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19 March 1980

USSR Report

CONSTRUCTION AND EQUIPMENT

(FOUO 2/80)

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USSR REPORT

CONSTRUCTION AND EQUIPMENT

(FOUO 2/80)

CONTENTS PAGE

METALWORKING EQUIPMENT

MACHINE-TOOL-INDUSTRY ACHIEVEMENTS IN THE 10TH FIVE-YEAR PLAN

Moscow STANKI I INSTRUMENT in Russian No 9, Sep 79 pp 1-2

[Article: "The Day of the Machine Builders--New Successes in Labor"]

[Text] The workers of the machine tool building and tool industry celebrated Machine-Builders' Day in the midst of a new upsurge of labor enthusiasm. In June 1979, the collectives of the enterprises and organizations of the branch celebrated the 50th Anniversary of Soviet Machine-Building which at the present time is the primary production-technical base providing the national economy and, above all, machine building, with the necessary metal working equipment and tools. In three years of the 10th Five-Year Plan the national economy of the Soviet Union has received almost 570,000 metal cutting machines, more than 112,000 forging and pressing machines, equipment for casting production in the amount of 319 million rubles, tools and process equipment in the amount of 2.7 billion rubles from the enterprises of the Ministry of the Machine Tool Industry.

The Yegor'yev Machine Tool Building Plant Komsomolets has mastered the series production of vertical gear-milling machines models 53A50 and 53A80 for the manufacture of gears 500-800 mm in diameter with a tooth length of 350 mm. The machine tools are distinguished by high precision of machining, and they are convenient to service and repair; their output capacity is almost twice the output capacity of the analogous machine tools of preceding models. The transition from the rough machining to finish machining is made automatically. The 53A50 and 53A80 model machine tools have been awarded the State Symbol of quality.

The collective of the Kolomenskiy Heavy Machine Building Plant has manufactured a special vertical lathe with digital display. The Ul'yanov Heavy and Unique Machine Tool Plant built a unique milling machine with digital program control. The enterprise has set to work on building a range of unique machine tools of digital program control with subsequent conversion to the manufacture of automated complexes.

The Vil'nyus Machine Building Plant Zhal'giris has mastered the production of automatic machines which perform horizontal milling, drilling and boring operations. They are equipped with a digital program control system and the set of necessary tools. They have 1.5 times higher output capacity than the preceding model of the analogous machine tool. The Stankokonstruktsiya Plant of ENIMS Institute has completed the basic work on building the automated ASK-10 complex designed to machine parts of complex configuration. All of the process operations, including the transport of the billets and finished products are automatic.

The Leningrad Machine Tool Building Plant imeni Il'ich has mastered the production of optical profile grinding machines equipped with a screen. These machine tools are designed to manufacture hard-alloy hob cutters used in automobile production. The use of such machine tools at the Gor'kiy Automobile plant has made it possible to release 40 gear-milling machines. An important advantage of the given machine tools is the presence of a special optical system which transmits the image of the machined section of the part on the screen magnified 25 to 50 times. This significantly increases the efficiency of machining and the quality of the finished parts.

The Odessa Milling Machine Plant imeni S. M. Kirov has mastered the series production of broad-universal milling machines equipped with a small computer. All of the operations and the machining conversions of the part and also the changes in the machining program are entered in the computer memory, after which the machining cycle is realized automatically.

Increasing the production output of the highest quality category is a subject of special concern for the branch workers. In 1978, the proportion of such output was 24% of the total production volume as proposed to 7.6% in 1975. The complexes of many of the enterprises of the Ministry of the Machine Tool Industry have achieved high results in improving the quality of their production.

The Minsk Machine Tool Building Plant imeni S. M. Kirov has certified all series machine tools of the new models for the State Symbol of Quality. Now the production of highest quality category will be about 65% of the total production of the enterprise.

At the present time half of the production of the Moscow Machine Tool Building Plant imeni Sergo Ordzhonikidze is marked with the State Symbol of Quality. The socialist obligations of the collective provide for exceeding this mark at the end of the Five-Year Plan. The machine tool builders have been helped in achieving this progress by the complex production quality control system in operation at the enterprise, an important element of which is competition for the right to work with a personal stamp. Now 400 advanced workers and production innovators have earned this right at the plant. The production output with the state symbol of quality has increased from 17.35% in 1976 to 58.6% in 1978 at the Kiev Machine Tool Building Production Association.

The creative cooperation of the collectives of the Moscow SKB AL and SS Special Design Office, the Moscow Automatic Line Plant imeni 50th Anniversary of the USSR and the GPZ-1 can serve as an example of highly effective work and a genuinely national approach to improving production quality. The Moscow Automatic Line Plant imeni 50th Anniversary of the USSR is one of the initiators of socialist competition to improve production quality under the motto "Guarantee of Production Quality from Design to the Finished Product."

The socialist competition of the branch enterprises for the production of machine tools and other equipment in accordance with united technical specifications started by the collective of the Moscow Machine Tool Building Plant "Krasnyy Proletariy imeni A. I. Yefremov has become widespread. At the present time more than 92% of the machine tools produced by the plant have the State Symbol of Quality.

This year a great deal of work has been in the branch to master new, more effective, high-output technological processes and also with respect to the introduction of means of mechanizing heavy and tedious operations into production. The Lipetsk Casting Plant Tsentrolit began the manufacture of machine tool beds awarded the State Symbol of Quality in the first quarter of 1979 for the model 3D722 machine tool. The weight of the bed has been reduced significantly, its external appearance has been improved because the spachtling and priming of the product are being done by a new process directly at the manufacturing plant.

The Odessa Special Design Office for precision machine tools under the Odessa Precision Machine Tool Plant imeni 25th Congress of the CPSU has designed a horizontal, milling-drilling-boring machine, model 6904VMF2 designed for simultaneous machining of a part from four sides. The machine tool equipped with digital program control system and tool holder will permit milling, boring, drilling, countersinking, drilling of holes and cutting of thread in parts made of cast iron, steel, nonferrous metals and plastics. The electroinductive coordinate reckoning system used in the machine tool, the guide rollers and the ball screw paths insure high output capacity and precision of the machining.

The Krasnodar Machine Tool Building Plant imeni G. M. Sedin manufactured the first lot of vertical lathes with digital program control and automatic tool holders which will make it possible to increase the output of parts by 2 to 3 times.

The new design of the semiautomatic manipulator developed by specialists of the Ryazan' branch of the State Process Planning and Experimental Institute Orgstankinprom can be used as an example of the mechanization of labor of the casting production workers. By using this manipulator one operator will be able to knock massive castings out of the molds.

Eight months of the fourth year of the five-year plan are behind us. The fate of the successful fulfilment of the plans and the adopted socialist obligations will be decided to a great extent in the present phase of production activity.

Summing up the results of the work that has been done, it is important to analyze with maximum depth and on a high theoretical level in accordance with the requirements of the 25th Congress of the Party and the November (1978) Plenum of the Central Committee of the CPS where and for what reasons losses are being permitted, what reserves must be put into operation, and how best to organize this matter.

It is necessary to take decisive measures with respect to the reduction and elimination of the losses of work time, the strengthening of labor and production discipline. The work experience of the enterprises where daily concern is shown for the young shifts and persistence is being developed deserves all manner of support. The duty of the production personnel is to instill in the young people a respect for the elected profession and to support their efforts to master the necessary skills.

It is necessary to remember that the goals of the five year plan with respect to production volumes and productivity of labor can be achieved primarily on the basis of reducing the labor and material expenditures, replacement of manual labor by mechanized. The enterprises are doing the right thing where personal creative schedules are being introduced into practice, cooperation with the scientific research institutions is being strengthened, complex brigades capable of solving the basic problems of technical reequipment of production are being created.

The introduction of the brigade forms of organization and wages constitutes an enormous reserve for improving the productivity of labor in our branch with respect to the final results. The improvement of the work practice in such brigades at the Orenburg Machine Tool Building Plant, the Kiev Automatic Machine Tool Plant imeni M. Gor'kiy, the Kolomenskiy Heavy Machine Tool Building Plant and at the plants of the other machine building branches indicates that in the brigade form of organization there are large reserves for improving the productivity of labor as a result of more complete use of work time, improvement of the qualifications of the workers, mastery of two or more professions by each member of the brigade.

The application of the brigade method of work at the Sverdlovsk Tool Plant has made it possible to increase the productivity of labor in the brigade by more than 25%. At the present time 30% of the industrial workers have been encompassed at the plant by brigade form of organization and wages with respect to the final result, 29 such brigades have been created in basic production and 39 in auxiliary production.

The most important condition of the growth of productivity of labor and technical progress of the branch is reduction of the times for introduction of the design and technological developments of the branch institutes into production and also reduction of the times for mastery of the established series of process equipment in production. The equipment created at the present time by the designers must insure high output capacity, precision and quality of the manufactured products. When creating new models of machine tools and equipment it is necessary to give special attention to improving the level of their automation. It is necessary to increase the output of multiple-tool machine tools with digital program control equipped with automatic tool-changing magazines, manipulators with program control, machines for precision casting, automatic and semiautomatic lines.

For the successful solution of the problems facing the branch in 1979 and to the end of the 10th five year plan, it is necessary to realize a complex of approved organizational and technical measures, including the following: capital construction of billeting enterprises, acceleration of their introduction into operation and assimilation of capacity; organization of specialized shops and sections for centralized manufacture of the means of mechanizing and automating heavy and manual operations; an increase in production and introduction of machine tools with digital program control and also an increase in their use coefficient; constant technical improvement of the manufactured machine tools and machines in accordance with the resolution of the Central Committee of the CPSU and the USSR Council of Ministers "On further development of machine building in 1978-1980."

It is necessary to observe the strictest regime of saving metal, fuel, energy and other material resources. In 1979 on the whole throughout the Ministry of the Machine Tool Industry, a reduction in the metal rolled products consumption norms by no less than 5.5% of the total consumption must be insured.

An important role in the fulfillment of the socialist obligations assumed in 1979 is played by the creative activity of the branch workers during the course of socialist competition. It is necessary to increase the effectiveness of the competition, direct it toward overfulfillment of the established production plans by more complete use of labor and material resources.

Celebrating Machine Builder's Day by new labor progress, the industrial workers, engineering and technical workers and office workers of the machine tool and tool industry are applying all of their skills and efforts to unconditional fulfillment and overfulfillment of the 1979 plan and the adopted socialist obligations.

10845
CSO: 1821

METALWORKING EQUIPMENT

UDC [658.2:621.924]:061.75

HUNDREDTH ANNIVERSARY OF THE MOSCOW GRINDING MACHINE PLANT

Moscow STANKI I INSTRUMENT in Russian No 9, Sep 79 pp 3-6

[Article by P. D. Petrenko, V. K. Starcstin, L. P. Karabchiyevskiy, V. K. Yermolayev]

The Moscow Grinding Machine Plant (Figure 1)[1] is an advanced precision machine building enterprise.

In 1879 a small "Boiler plant" (later renamed "Mechanical and Cast Iron Casting Plant") was started at the location of the modern plant. It produced boilers, oil tanks, and machines for making cigarette cases and small castings.

During the first years of Soviet power the plant (which came to be called "Samotochka") mastered the production of shapers, lathes and slotting machines. The rebuilding of the plant which was started in 1931 made it possible to tool up for the series production of grinding machines for various purposes in 1938. In the same year, the enterprise was named the Moscow Grinding Machine Plant.

During World War II, the plant made a worthy contribution to the strengthening of the military potential of the country, manufacturing machine tools for the defense industry and for the production of ammunition.

During the postwar period the plant continued assimilation and production of grinding machines, which were extremely necessary to the restoration of the national economy of the country. In addition to the series produced universal (circular and surface grinding) machines, the manufacture of 20 models of specialized grinding machines was mastered. In the 1950s, the plant began the production of gear grinding and spline-grinding machine tools, modesl 5831, 586, 5860A, 3451, and so on. In 1963, the second rebulding of the plant was completed, and a thermostated facility (Figure 2) was put

[1]Not reproduced.

into operation which was necessary for the production of gear grinding machine tools of high and especially high precision. This facility included the assembly and testing shops, a section for finish machining parts and a laboratory complex. In the production facilities and the measuring laboratories of the facility a stable temperature and humidity of the air are maintained. Increased vibration insulation of the assembly stands is insured by specially designed foundations.

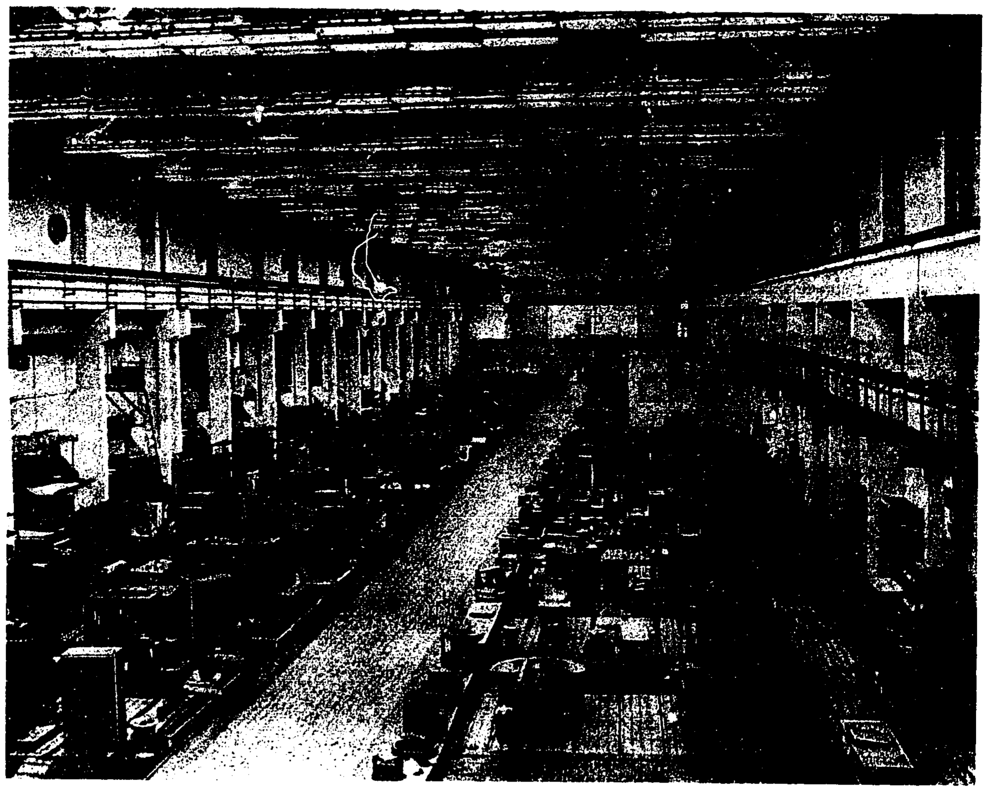

Figure 2. Thermostated facility.

Unique equipment was set up in the shops of the plant; plano-grinding machine tools with bench dimensions of 2000 × 6000 mm; especially high precision grinding machines, gig boring machines and gear finishing machines; machine tools with digital programmed control (Figure 3).

For the last 10 years the Moscow Grinding Machine Tool Plant has specialized in the production of precision gear and spline-grinding machines. The volume of commercial production of the plant in 1978 was almost double the analogous index in 1968. At the present time the enterprises producing

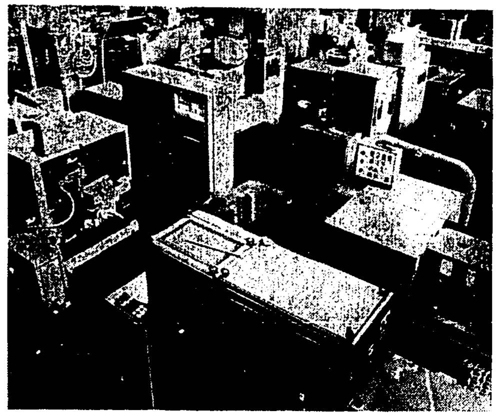

Figure 3. Section for machine tools with digital programmed control

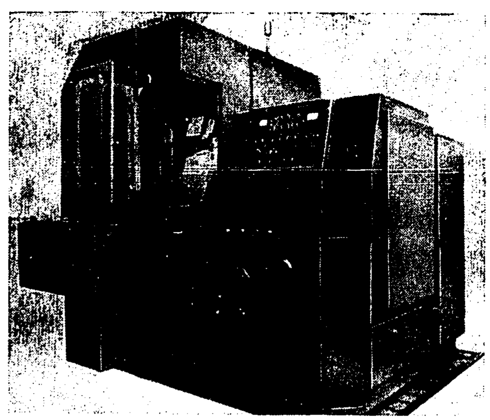

Figure 4. Universal model 5A841 gear grinding machine with digital programmed control.

various grinding machines (about 100 models), including universal and specialized gear-grinding machines and semiautomatic machines for machining gears, gear-shapers, shavers, universal and specialized spline-grinding machines, semiautomatic and automatic machines for machining splined bushings, shafts and broaches. In addition to the enumerated machine tools, the plant produces special machine tools for various purposes: for machining the valves of internal combustion engines; for machining nonresharpenable cutting tips from hard alloy; for grinding bearing rings; for precision diamond machining of the flat surfaces of parts made of materials that are difficult to machine; for gear milling of the spline shafts; for continuous drawing of turbine vanes from materials that are difficult to machine, and so on.

The description of a number of universal and specialized machine tools produced at the present time by the Moscow Grinding Machine Tool Plant is presented below.

The universal gear grinding machines (precision class V) manufactured on the basis of the model 5A841 machine tool (Figure 4) are designed for grinding (by the method of hobbing with unit division) of an evolvent profile of cylindrical straight-tooth gears and spiral wheels under the conditions of unit and series production. The machining is done by a conical disc. The machine tools operate in an automatic cycle; by using a cyclic program control system, first the number of passes, the amount of feed and the dressing conditions of the disc are established. The machine tools in this range provide for manufacturing gears of fifth-degree precision. When machining a straight-tooth gear with 6 mm modulus, 50 teeth and 40 mm rim width on the model 5A841 machine tool, the following precision parameters of the product are obtained: the difference of adjacent circular pitch of 0.009 mm; accumulated pitch error 0.024 mm; profile error 0.006 mm; tooth direction error 0.006 mm; roughness of the machine surfaces R_a = 0.63 microns.

The grinding of the complete profile of the depression of the gear in one path of the bench (provided for by the machine tool design) insures high machining efficiency. On the machine tools gears are also machined with modified tooth profile. The hobbing and division mechanisms are adjusted by replaceable gears and lever of the hobbing mechanism.

The model 5851 and 5853 (precision class A) universal gear-grinding machines are designed for grinding the evolvent profile of cylindrical gears with straight and helical peaks. The machining is done by two plate-type discs. The model 5851Ts (Figure 5) and 5853Ts machine tools equipped with cyclic program control systems have been designed on the basis of the machine tools. The following operations are automated with their help: in-feed after each pass; a change in cycle from two-sided to one-sided; a change in bench feed (from rough to finish). The machine tools provide a machining precision of no less than fourth degree. When machining a straight-tooth gear with modulus 4 mm, 60 teeth and rim width of 32 mm on the model 5851Ts machine tool, the following precision parameters of the product are obtained: difference of adjacent circular pitch 0.003 mm; accumulated pitch error 0.011 mm; profile error 0.004 mm; tooth direction error 0.004 mm; roughness of the machined surfaces R_a = 0.63 microns.

The short kinematic chain and special dividing discs insure high precision of division. The output capacity of the model 5851Ts machine tool is higher than the capacity of the model 5851 machine tool by 1.5-2 times as a result of the possibility of multiple machine tools servicing.

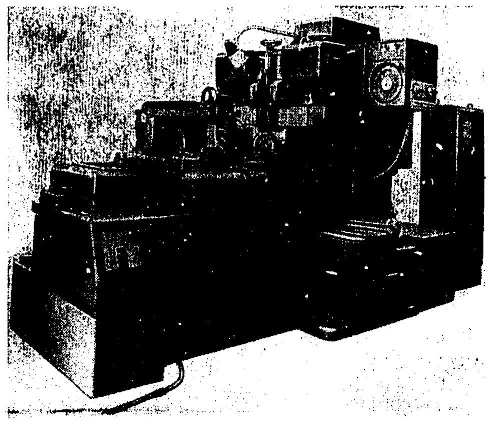

Figure 5. Model 5851Ts universal gear grinding machine with digital programmed control.

On the basis of the model 5851 machine tool, the model 5M851 machine tool has been built which is equipped with an automatic regulation system which by varying the rate of longitudinal displacement of the bench will maintain the cutting power at the given level.

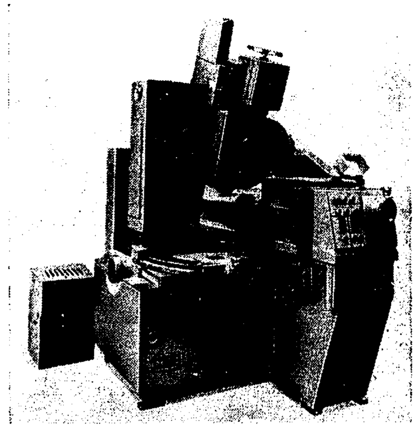

Figure 6. Model 5A893S special gear grinding machine.

The special model 5891 and 5A893 gear grinding machines (accuracy class A) are designed for final machining of the evolvent profile of the shapers, the

Figure 7. Model 3B451VF universal spline-grinding machine with digital programmed control.

shavers and the measured gears with high degree of precision under the conditions of unit and series production. The machining is done by a flat disc by the hobbing method with unit division, using the evolvent former.

The machine tools insure a machining precision of no less than third degree. On the basis of these machine tools, the model 5891S and 5A893S machine tools (Figure 6) were built which were designed for grinding high-precision shavers and gear shapers (class AA) and also standard gears. When machining a gear with modulus 9 mm, 30 teeth and rim width of 40 mm on the model 5A893S machine tool, the following precision parameters of the product were obtained: difference in adjacent circular pitch 0.003 mm; accumulated error of the circular pitch 0.01 mm; profile error 0.003 mm; tooth direction error 0.003 mm; surface roughness R_a = 0.16 microns. The advantages of the model 5A893S machine are increased rigidity of the division and feed mechanisms and also convenience of adjustment of the division mechanism.

Universal Spline-grinding Machines. The semiautomatic and automatic spline-grinding machines of precision class P and V manufactured on the basis of the model 3B451 machine tool are designed for grinding splined shafts and broaches under the conditions of unique, series and mass production. The machining is carried out by one disc or a block of two or three discs. The machining cycle, including the transition from the rough conditions to finish is completely automated; the installing and removal of the product are manual. The automatic cycle provides for removal of the rough allowance (in each groove) without division, which significantly increases the efficiency of the machining.

The machine tools are equipped with a high-precision division mechanism (without replaceable gears) with hydraulic drive which insures continuous regulation of the division rate. The rolling guides of the carriage of the

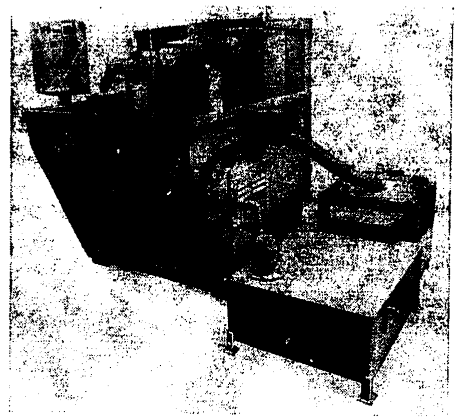

Figure 8. Model MSh-289 special automatic grinding machine.

grinding disc guarantee easy movement and precision of displacement of it. The roller guides of the bench insure uniform movement of it at low speeds. The precision of positioning the bench with respect to the bed is within the limits of 0.5 mm, which offers the possibility of machining splines do not have exit of the disc in the direction of the division mechanism. The precision of machining a splined shaft 8 × 42 × 48, 350 mm long on the semiautomatic 3B451V-IV is characterized by the following data: difference in adjacent circular pitch 0.002 mm; accumulated error of the circular pitch 0.004 mm; nonparallelness of the sides of the splines of the groove axis and nonuniformity of width of the splines 0.005 mm in a length of 300 mm; roughness of the machined surface R_a = 0.63 microns.

The model 3B451VF2 machine tool with digital programmed control (Figure 7) has automatic feed of the grinding disc carriage by a screw from the model YeS-5 stepping motor. The angle of rotation of the motor depends on the number of pulses coming from a special unit.

Special Machine Tools. The automatic spline-grinding machines, models MSh-278, MSh-279, MSh-293 and MSh-294 are built into automatic lines and are designed for machining shafts under mass production conditions. The machine tools provide for automatic conditions of machining the part: loading, orientation, clamping, grinding and unloading.

The model MSh-259 machine tool (precision class B) is designed for precision diamond machining of the flat surfaces of the parts (plates, discs, rings, and so on) made from materials that are difficult to machine (silicon, germanium, ceramic, devitrefied glass such as pyroceram, ferrites, and so on). The precision of machining germanium tips is characterized by the following data: nonplaneness of 0.0015 mm, nonparallelness of 0.001 mm, roughness of the machine surfaces R_a = 0.08 microns.

The model MSh-289 automatic machine (Figure 8) of precision class B is designed for grinding the faces and the tips of the multifaceted, nonresharpenable hard-alloy tips under the conditions of large-series and mass production. The dimensions of the machined tips are as follows: diameter of the inscribed circle 6.35-25.4 mm, height to 20 mm. The grinding is done by the end of a cup-shaped diamond disc. The machine tool is equipped with a cyclic program control system manufactured with the application of semiconductor devices and printed circuits, and it insures automatic machining conditions (loading, clamping, feed of the product, operating feed, dwelling, division, forming, withdrawal and release). The machining precision of the tips with respect to the diameter of the inscribed circle is 0.025 mm.

The model MSh-273 two-way end grinding machine (precision class B) is designed for simultaneous machining of two ends of the rings of instrument bearings (3-13 mm in diameter and 2-8 mm high) and also parts of the ring and tip type under the conditions of large series and mass production. The original kinematic system of the machine tool insures complete automation of all the servomovements (including loading, control and adjustment), which guarantees high efficiency and precision of the machining.

When machining an outside bearing ring 10.2 mm in diameter, the following precision parameters are obtained: inconstancy of the ring width 0.002 mm; nonplaneness of the ends 0.001 mm; different dimensionalities 0.005 mm; surface roughness R_a = 0.32 microns. The machining output capacity is 9600 pieces/hour.

At the Moscow Grinding Machine Plant Scientific Research Work is being performed with respect to the creation of new methods of machining gears and spline shafts. New methods of gear and spline grinding are being developed on the basis of the machine tools manufactured by the plant.

The grinding of gears from an integral hardened billet (without preliminary gear shaping or gear milling) is used on the machine tools operating by a profile or conical disc. On the basis of the model 5A841 machine tool, the MSh-321 machine tool has been designed which is to be used to grind gears (modulus 6 mm and up to 80 mm in width) from an integral billet. The gear billets are made from alloy construction steels (40KhN, 40KhGR, 40KhNMA, 50Kh, 50KhN, and so on) and they are subjected to volumetric hardening in advance. The distinguishing features of this method are low specific cutting power and low thermal stress commensurable with the analogous indexes for ordinary gear grinding. The precision of machining the gears by the experimental data corresponds to sixth degree, the surface roughness R_a = 0.63 to 1.25 microns. The efficiency of the developed grinding method (by comparison with the existing one) will increase by 1.2 to 2 times depending on the type of gear cutting and gear grinding machines.

The method of in-feed gear grinding is designed for machining previously cut gears from quenched steel in one pass on machine tools which operate by plate discs with unit division. The machining is done with high hobbing speed. A special electronic system permits automation of the machining process. The parameters of the machined gears are as follows: modulus 2-10 mm;

number of teeth 10-200; outside diameter 50-320 mm; width to 30 mm. The productive of average dimensions corresponds to fourth to fifth degree precision. The efficiency of this grinding procedure (by comparison with the usual gear-grinding on the model 5851 machine tool) is increased by 1.5-4 times depending on the type and size of the products.

The hobless method of grinding is designed for machining quenched spiral wheel cylindrical gears with unit division. With this procedure the profile and the helical line of the tooth are formed with helical displacement of the billet along its axis. The parameters of the machined gears are as follows: modulus 2-10 mm; 10-100 teeth; outside diameter 30-800 mm; angle of inclination of the teeth 18-45°. It is expedient to machine wide gears by the proposed method. The machining precision (according to the experimental data) corresponds to fifth degree; the surface roughness $R_a = 0.32$ microns. The grinding efficiency by the hobless method is twice as high as on the model 5A841 machine tool and 3 times higher than on the model by the 5851 machine.

The procedure of electrochemical gear grinding is designed for machining gears, shapers and shavers made of difficult to machine alloys and steels on the model 5891 machine. The machining is done by a current-conducting grinding disc by the hobbing method; here a liquid electrolyte is fed into the cutting zone (by the hydroaerodynamic method). The disc (the cathode) and the product (the anode) are connected to a dc power supply. The removal of the machining allowance takes place as a result of abrasive cutting and electrochemical solution. The electrochemical grinding increases the machining efficiency by 2 to 2.5 times (and when machining a hard alloy by 3 to 4 times) by comparison with the traditional method of grinding on the model 5891 machine tool.

The method of deep grinding of splines with removal of the complete machining allowance is designed for machining the previously notched splined shafts made of quenched steel in a limited (to two) number of passes. The peculiarity of the method is that the machining is done while moving the product at a speed of 0.3 to 5 m/min, and the depth of cutting is equal to the grinding allowance. The precision of the single-pass grinding of a spline shaft (10 × × 60 × 70) with a grinding length of 100 mm and 0.3 mm allowance is characterized by the following data: difference in adjacent circular pitches 0.01 mm; accumulated circular pitch error 0.015 mm; nonparallelness of the sides of the splines of the shaft 0.01 mm.

The method of deep grinding of splines from an integral quenched billet (without preliminary spline milling) is designed for machining spline shafts from alloyed construction steel (40KhN, 40KhNMA, 50KhN, and so on) subjected to preliminary improvement or volumetric quenching. The distinguishing characteristics of the method are low displacement rate of the product (0.01-0.5 m/min) and significant depth of cutting equal to the total height of the spline. The precision of machining the spline shaft (8 × 42 × 48) with a grinding length of 100 mm is characterized by the following data: difference in adjacent circular pitches 0.02 mm; accumulated circular pitch error

0.025 mm; nonparallelness of the sides of the splines of the shaft 0.02 mm. The deep splining is characterized by the fact that the machining done by porous grinding discs with intense cooling (pressure of the cooling and lubricating liquid 15-25 kg/cm^2, flow rate to 200 liters/min).

The efficiency of deep grinding (by comparison with ordinary spline grinding on model 3451 machine tools) increases by 1.5 to 2.5 times depending on the type and size of the products. For mass production of spline shafts, a special MSh-322 semiautomatic spline grinding machine has been designed (on the basis of the model 3B451 machine) for deep grinding of the shafts.

The collective of the Moscow Grinding Machine Tool Plant will be striving also in the future to build high-output equipment, improve its efficiency and quality, and solve the problems stated for the enterprise on a high scientific and technical level.

10845
CSO: 1821

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200060026-5

METALWORKING EQUIPMENT

UDC 621.9.06-529-182.3

MACHINING ERRORS ON MACHINE TOOLS WITH DIGITAL-PROGRAM CONTROL

Moscow STANKI I INSTRUMENT in Russian No 9, Sep 79 pp 8-11

[Article by M. I. Koval', G. A. Igonin]

[Text] The manufacture of a part on a machine tool with digital program control includes the following basic steps: the compiling of the control program; the adjustment of the machine tool and the control system; the installation of the billet and tool on the machine tool; the machining of the billet in accordance with the program; control of the finished part. The machining errors occur in each of the steps for different causes, the total number of which can reach several dozen.

The largest number of components of the resultant machining error occur on machine tools with outline type digital program control systems (see Figure 1). All of these components can be divided into three groups: 1) caused by the digital program control system; 2) caused by the SPID [machine tool, attachment, tool, part] system; 3) caused by external factors. A comparative quantitative analysis is made below of the errors introduced by the various elements of the machine tool and the digital program control system. The errors introduced by the external factors (for example, the monitoring and measuring means) are not taken into account for they are not characteristic of the machine tool and digital program control system complex.

Analyzed Digital Program Control Systems. Figure 2 shows the functional diagrams of three outline digital program control systems widespread in modern machine tools. All of them have a builtin interpolator, they provide linear-circular interpolation, tool correction with respect to length and diameter, automatic acceleration and deceleration of the drive with given intensity, automatic return of the machine tool assemblies to the initial position and other functions. A ball-screw pair was used in the feed mechanism.

The theoretical difference of the systems from the point of view of machining precision is the servodrive structure. In the system according to Figure 2,a, step electrohydraulic or electric power drives are used. Such systems are open systems: there is no sensor in them to monitor the execution of the commands for displacement of the machine tool assemblies or the actual position of the servoelement. Therefore the errors in working out control pulses by the step drive and the errors of the ball-screw pair are not corrected, and they enter into the resultant machining error.

In the closed system according to Figure 2,b, a thyristor or transistorized servodrive is used based on a dc electric motor. The circular position sensor of the "resolver" type installed on the ball screw insures precision development of the given angle of rotation of the screw by the electric motor. However, the errors in the ball-screw pair, just as in the system according to Figure 2,a, are not corrected.

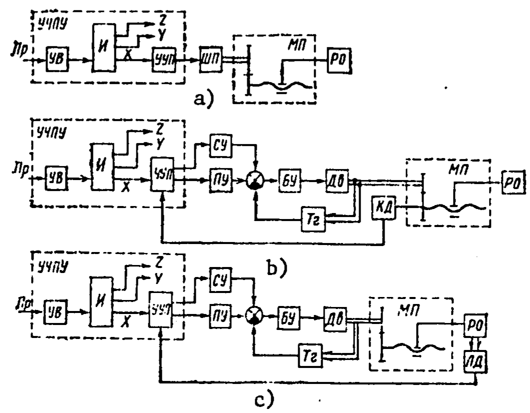

Figure 2. Functional diagrams of the outline digital program control system: a -- open system with step drive; b -- closed system with circular position drive installed on the lead screw; c -- the same with linear position sensor installed on the servoelement of the machine tool (Пр -- program; YB -- input circuit; YYП -- drive control; ШП -- step drive; И -- interpolator; ПY and CY -- travel and speed accelerators; БУ -- control module; Дв -- motor; Тг -- tachogenerator; MП -- feed mechanism; PO -- servoelement; КД and ЛД -- circular and linear position sensors; X, Y, Z -- coordinates machine tool).

In the closed system according to Figure 2,c, the linear position sensor installed directly on the servoelement of the machine tool provides for precision development of the control pulses by the shifted assembly. All of the errors of the servodrive and the ball-screw pair are corrected.

At the present time the digital program control system according to Figure 2,b is used the most widely. With respect to structure and properties of the servodrive it occupies an intermediate position between the system according to Figures 2,a and c. Therefore in the given article the processing errors are analyzed for the machine tool with the system according to Figure 2,b, and for analysis of the machine tool with an other system, the necessary refinements are introduced into the results.

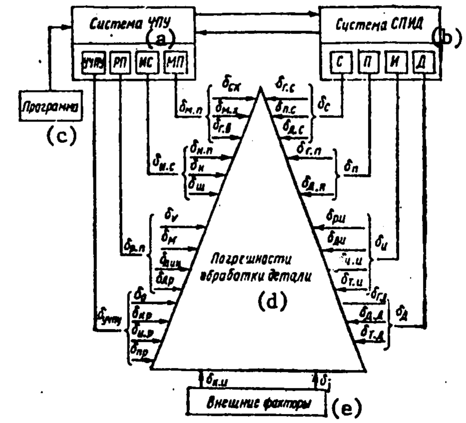

Figure 1. Machining error components and sources of their occurrence on a machine tool with a outline digital program control system: УЧПУ -- digital program control circuitry; РП -- adjustable drive (servodrive); МП -- feed mechanism; ИС -- measuring system; С -- machine tool; П -- attachment; И -- tool; Д -- part; $\delta_{УЧПУ}$, $\delta_{Р.П}$, $\delta_{И.С}$, $\delta_{М.П}$, $\delta_{С}$, $\delta_{П}$, $\delta_{И}$, $\delta_{Д}$ -- machining error components caused by the corresponding elements of the digital program control system and the SPID [machine tool, attachment, tool, part] system; $\delta_{ПР}$ -- programming error; $\delta_{И.Р}$ -- interpolator error (calculated); $\delta_{КР}$ -- interpolator corrector errors; δ_0 -- error from formation of the "initialization" instruction for the machine tool assemblies; $\delta_{ДР}$ -- error from the drift of the servodrive module characteristics; $\delta_{М}$ -- moment error of the drive; $\delta_{ДИН}$ -- dynamic drive error; δ_{v} -- velocity error of the drive; $\delta_{Ш}$ -- intrastep error of the sensor; $\delta_{Н}$ -- accumulated sensor error; $\delta_{Н.П}$ -- normalizing converter error; $\delta_{Г.В}$ -- geometric error of the lead screw; $\delta_{М.Х}$ -- error from the play in the ball-screw pair; $\delta_{СК}$ -- error from the discontinuous nature of movement of the assemblies for small feeds; $\delta_{Г.С}$ -- geometric error of the machine tool; $\delta_{П.С}$ -- error from reorientation of the machine tool assemblies; $\delta_{Д.С}$ -- error from deformation of the machine tool assemblies; $\delta_{Г.П}$ -- geometric error of the attachment; $\delta_{Д.П}$ -- error from deformation of the attachment; $\delta_{Р.И}$ -- dimensional error of the tool; $\delta_{Д.И}$ -- error from deformation of the tool; $\delta_{И.И}$ -- error from tool wear; $\delta_{Т.И}$ -- thermal error of the tool; $\delta_{Г.Д}$ -- geometric error of the part; $\delta_{Д.Д}$ -- error from deformation of the parts; $\delta_{Т.Д}$ -- thermal error of the part; $\delta_{К.И}$ -- error in the control measurements of the part; δ_j -- error from other external factors.

Key: a. digital program control system
b. SPID system
c. program
d. part machining errors
e. external factors

The present analysis is performed as applied to heavy vertical milling machines, models 654F3 and 654RF3 with digital program control (the latter is equipped with a six-position revolving head). In the series execution the machine tools of both models are equipped with the digital program control system according to Figure 2,c with linear position sensor of the DLM-11 type. For investigation of the precision of the machining of the model 654RF3 machine tools, they were equipped with a system according to Figure 2,b with circular position sensor of the VTM-1V type installed on the lead screw.

As the machining precision indicator let us use the dimension error. For convenience of analysis, the machining on machine tools with digital program control is divided into position and outline. Considering the theoretically different nature of functioning of many of the elements and assemblies of the digital program control system and the SPID system during this type of machining, it is expedient to consider the errors of each type of machining separately.

In order to estimate the machining precision in these cases it is proposed that two types of dimension errors be used: 1) the position machining error, that is, the deviation of the linear dimensions of the machined part (the distances between the machined planes and the grooves, the distances between centers, holes, height of the steps, and so on) from those given in the drawing; 2) outline machining error, that is, the deviation of the dimensions of the machined outline of the part (arc, curvilinear surface, and so on) from that given on the drawing.

The position machining error, as a rule, fully enters into the outline machining error. Therefore it is expedient to analyze the position machining error and then supplement it with the components caused by the peculiarities of the outline machining. Here, for comparative analysis of the error components it is possible not to use the probability methods, and it is sufficient to compare the maximum possible values.

The analysis is performed for the cases of finished machining of flat parts with linear dimensions to 630 mm (maximum displacement along the Y-coordinate of the machine tool model 654F3) by an end-cutter 18 mm in diameter for a feed of s = 400 mm/min; other peculiarities of the machining regime are noted below when analyzing the individual components.

The position machining error is formed when the displaced assemblies of the machine tool are stationary, or only one of them moves with constant velocity. All of the basic devices and elements of the digital program control system and the SPID system participate in the formation of this error. However, not all possible error components (Figure 1) occur during position machining.

Errors of the Digital Programming Control. The basic factors determining the errors introduced by the digital program control circuitry are the discreteness of the device, the principle of calculating the trajectory (the interpolation principle) and the principle of constructing the device for initializing the machine tool assemblies. In the majority of the Soviet digital program control circuits the discreteness is 10 microns. When compiling the program the precision of assignment of the dimensions cannot exceed the discreteness value; Consequently, the maximum possible programming error $\delta_{\pi p} = \pm 5$ microns.

The discreteness of the correction of the dimensions of the tool with respect to length and the radius is equal to the discreteness of the digital programmed control device, that is, the maximum value of $\delta_{kp} = \pm 5$ microns. For position machining the calculation of the curvilinear trajectories is absent, and the interpolation of the movement of the assembly with respect to one coordinate is realized without errors; therefore $\delta_{н.р} = 0$. The initialization of the assemblies of the machine tool has sensitivity equal to the discreteness; therefore the maximum value of $\delta_0 = \pm 5$ microns.

Servodrive Errors. In modern servodrives in addition to the main feedback with respect to path, rigid feedback with respect to speed of motor is used. This and also other structural solutions, permit significant decrease in the servodrive errors. Thus, in the ETZS1-G type servodrive and in the drive with the BU-3608 converter the value of the error $\delta'_{др}$ (from drifts of the converter characteristics), as the tests demonstrated, does not exceed $\pm(2-3)$ microns. As it a result of the feedback with respect to speed in the indicated drives, large values of the amplification coefficients with respect to moment (to $1.1 \cdot 10^6$ kg/mm) are realized and the moment error δ_M does not exceed ± 2 microns with full load of the drive.

Errors of the Measuring System. In the investigated digital program control system, the VTM-1V type rotating transformer is used as the position sensor. In the normal execution its error does not exceed 17', which in case of insulation of it on the lead screw with a pitch of 10 mm and with discreteness of 10 microns (division of the pitch by 1000) causes an intrastep error of the sensor $\delta_{ш} \leqslant 8$ microns. Using an improved "resolver" type sensor, it is possible to reduce this error to 3-5 microns. The error $\delta_{H.П}$ of the normalizing converter during position machining does not exceed ± 2 microns [1].

Feed Mechanism Error. In the digital program control system with respect to Figure 2,b the feed mechanism introduces two components into the position machining error: $\delta_{Г.В}$ caused by imprecision of manufacture (with respect to pitch and over the entire length) of the lead screw, and $\delta_{M.X}$ caused by play in the ball-screw pair. The values of $\delta_{Г.В}$ for the screws of different precision class are presented in the table [2].

Theoretically the ball-screw pair can be made without play [2]. However, instructions of the model 654F3 machine tools at the manufacturing plant and in operation demonstrated that the total play reaches 50 microns. Under the least favorable conditions this causes a machining error $\delta_{M.X}$ of the same magnitude.

Screw precision class	Admissible error $\delta_{Г.В}$, microns								
	Within limits of 1 turn of screw	Over the length, mm							
		to 50	>50 to 125	>125 to 250	> 250 to 400	>400 to 630	> 630 to 1000	>1000 to 1600	>1600 to 2500
В	4	5	6	8	10	16	25	40	63
П	6	8	10	12	16	25	40	63	100
Н	8	12	16	20	25	40	63	100	160

Machine Tool Errors. The component $\delta_{Г.С}$ caused by the geometric imprecision of the machine tool depends on the dimensions of the machine part and on the executed operation. Thus, on a vertical milling machine when machining a groove parallel to the X-axis using an end-type cutter, an error is introduced which is caused by the nonrectilinearity of the movement along the X-coordinate in the horizontal plane. The magnitudes of such errors can be taken from the machine tool certificate (for the model 654F3 machine tool the nonrectilinearity of displacement is 16 microns over a length of 630 mm and 25 microns over a length of 1250 mm).

The error components caused by elastic deformations are introduced by all elements of the SPID system. The process of the formation of these components is qualitatively identical. Therefore they are calculated for the bearing system of the machine tool, and for other elements (the attachment, tool, part) only quantitative estimates are presented below.

The error $\delta_{д.с}$, caused by elastic deformation of the bearing system of machine tool is determined by the normal component P_H of the cutting force and the rigidity c of the bearing system in the direction perpendicular to the machined surface, that is, $\delta_{д.с} \doteq P_H/c$.

It is expedient to isolate the constant and variable components of $\delta_{д.с}$. The constant component corresponding to machining with P_H = const and c = = const can be compensated for (by means of the tool size correctors) with precision to 0.5 of the discreteness. The variable component caused by fluctuations ΔP_H of the normal component of the cutting force and ΔC of rigidity in the machining process, can reach several millimeters on heavy milling machines during the rough pass. To compensate for it, adaptive control is needed, and in the absence of adaptive control, a finish pass.

Let us assume that for the finish mode of milling by an end-type cutter 18 mm in diameter with s = 400 mm/min ΔP_H = 10 to 15 kilohertz. The maximum experimentally obtained value of the rigidity of the bearing system of the machine tool in this group (model 654) $c_{max} = 20 \cdot 10^3$ kg-force/mm; the minimum $c_{min} = 5 \times 10^3$ kg-force/mm [3]. Under these conditions the error from fluctuation of the cutting force $\delta'_{д.с} = 2\Delta P_н/(c_{max} + c_{min}) = 0.8$ to 1.2 microns; the error from fluctuation of the rigidity (with a mean value of ΔP_H equal to 12.5 kilohertz) $\delta''_{д.с} = 12{,}5\,(1/c_{min} - 1/c_{max}) = 1{,}8$ microns, and the resultant variable component $\delta_{д.с} = \sqrt{(\delta'_{д.с})^2 + (\delta''_{д.с})^2} = 1{,}97$ to 2.17 microns.

In all machine tools, especially the heavy ones, the phenomenon of reorientation of the assembly on reversal of motion is well known. The errors in manufacturing the guides, the wedges, the cleats, the imprecision of adjusting the elements of the guides and the feed drive mechanism -- all of these lead to the fact that on reversal of motion the assembly is rotated relative to the displacement axis. The error introduced by reorientation into the dimensions of the part depends on the location of the part at the time of reversal and the type of operation performed. In the worse case in the investigated digital program control system the error from reorientation enters fully into the position machining error. For the tested three model 654F3 machine tools the value of $\delta_{\pi.c} = 5$ to 10 microns.

The attachment error can be caused by its geometric imprecision ($\delta_{\Gamma.\pi}$) or its elastic deformations ($\delta_{з.п}$). The error of the first type is determined by the basing system and the precision with which the base surfaces of the attachments are manufactured. Thus, in the case of installing a billet on a cylindrical pin with respect to a sliding seat of second class precision this error is within the limits of ± 8.5 microns [4]. The error from the deformations of the attachment calculated analogously to the error from deformation of the bearing system of the machine tool, $\delta_{д.п} \leqslant 0{,}5$ to 1 micron.

Tool Error. The error $\delta_{р.и}$ are caused by deviations of the tool size in modern digital programmed control circuits can be corrected with precision to 0.5 of the discreteness. Inasmuch as the latter has already been taken into account when analyzing the digital program control circuit it is possible to consider that $\delta_{р.и} \approx 0$.

The deformations of the tool are the largest when machining by small-diameter end-type cutters. On the model 654F3 machine tool when machining in the above-investigated finish mode using the milling cutter 18 mm in diameter with a rigidity $c_{\phi p} \approx 10^3$ kg/mm the component $\delta_{д.и} \approx 10$ to 15 microns.

The error caused by the dimensional wear of the tool for the case of cylindrical milling can be estimated (in microns) by the formula of [5] $\delta_{и.и} = u_н + u_0 [l/(10^6 s_z z)]\, \pi d_{\phi p} \psi_к / 360$, where u_H is the initial wear of the cutter, microns; u_o is the relative wear, microns/km; ℓ is the length of the machined area, mm; z is the number of teeth of the cutter; s_z is the feed per cutter tooth, mm; $d_{\phi p}$ is the diameter of the cutter, mm; ψ_k is the angle of contact of the cutter with the part, degrees. In turn, $\psi_k = \arccos(1 - 2t/d_{\phi p})$, where t is the depth of milling, mm.

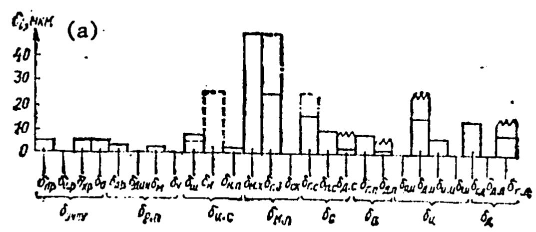

Figure 3. Diagram of the position machining dimension error components: solid lines -- error components in the system according to Figure 2,b; dash-dot lines -- the maximum value of the individual components for maximum displacement on the machine tool (1250 mm); dashed lines -- variation of the errors in the system (according to Figure 2,c by comparison with the system in Figure 2,b; the broken lines are the errors, the maximum value of which depends on the machining conditions.

Key: a. microns

For the finish milling modes, when $t \leq 0.5$ mm and $\ell < 10^5$ mm, $\delta_{и.и} \approx u_и$ and for various materials it is 2-7 microns, exceeding these values only in individual cases [5].

The thermal component $\delta_{т.и}$ of the tool error during finish modes and quide intense cooling can be decreased to negligibly small values, and therefore it is not taken into account during the given analysis [5].

Part Errors. The geometric component $\delta_{г.д}$ is caused by imprecision of the seats of the billet and for the adopted basing system does not exceed ± 13.5 microns. The error $\delta_{д.д}$ from the elastic deformations of the part for the analized machine tool is taken equal to zero. For the cases where the rigidity of the part is comparable to the rigidity of other elements of the SPID system, it can be estimated analogously to how this was done above for the bearing system.

The machining error component $\delta_{т.д}$ caused by thermal deformation of the billet during cutting can be estimated by the known [5] expression $\delta_{т.д} = \theta LT$, where θ is the coefficient of linear expansion of the billet material; L is the controlled linear dimension; T is the heating of the billet. For example, if a cast iron billet (L = 630 mm) is heated by 1° C during cutting, then $\delta_{т.д}$ = 7.56 microns.

The investigated components of the resultant position machining error are presented in Figure 3. All of the components are shown as positive; in the general case they can have any size.

The outline machining error is formed during mutual displacement of the tool and the part simultaneously with respect to servo axes. It includes all the position machining error components and, in addition, the errors caused by the forming movement of the machine tool assemblies.

The additional error $\delta_{u.p.}$ of the interpolator is caused by approximation of the curvilinear trajectories by segments of straight lines. The linear-circular interpolators of the Soviet digital program control circuits have an interpolation error close to discreteness, that is, in the majority of cases $\delta_{u.p.} = \pm 10$ microns.

During outline machining the servodrive introduces two additional components: dynamic $\delta_{\text{дин}}$ caused by the transient processes in the servodrive when working out the control inputs and velocity δ_v caused by various amplification coefficients with respect to the speed of the servodrives of different coordinates (during two-coordinate machining).

The error $\delta_{\text{дин}}$ is determined by the type of control input and the dynamic properties of the servodrive. In practice when machining the outlines of variable configuration (for example, inside angles) in order to reduce the dynamic errors an equidistant radius $R_e = 1$ to 5 mm is introduced into the trajectory of motion of the center of the cutter.

It has been established experimentally that for s = 400 mm/min and $R_e = 3$ mm for the ETZS1-G drives at a cutoff frequency of the open servodrive of 25 sec^{-1} and a mass of the dissipated assembly of 2.65 $kg\text{-}sec^2/cm$ the dynamic error $\delta_{\text{дин}} \approx 40$ microns. Of course, this value is only an estimate, for it can fluctuate in both directions depending on the quality of adjustment of the drive and other factors.

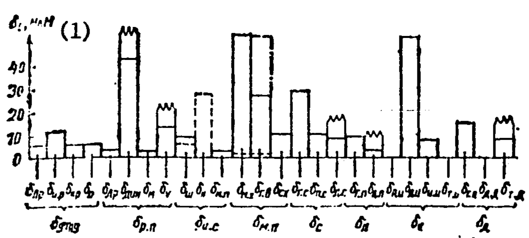

Figure 4. Diagram of the outline machining dimension error components (notation the same as in Figure 3).

Key: 1. microns

For nonlinear characteristics of the servodrive elements (deviations of the characteristics: path amplifier ±10%, velocity amplifier ±2.5%, tachogenerator ±2%) with s = 400 mm/min the value of $\delta_v = \pm 12$ microns [6].

The additional error δ_{ck} is determined by the discontinuous nature of movement of the assemblies in small feeds. The tests run on the model 654RF3 machine tool (TSAM slide guides -- cast iron) demonstrated that $\delta_{ck} = 5$ to 10 microns.

The additional error of the SPID system for outline milling is caused by peculiarities in the machining of the inside angles. In the general case in this mode it is necessary to consider the static component of the deformation of the machine tool elements connected with an increase in the cutting force as a result of variation of ψ_k at the apex of the angle and the transitional dynamic error caused by a discontinuous decrease in cutting force at the time of changing the trajectory of motion. The introduction of the equidistant radii into the trajectory of motion of the center of the cutter permits the rate of variation of the cutting force at the apex of the angle to be limited and correspondingly, the transition dynamic error to be diminished.

The error $\delta_{\text{д.с.}}$ caused by static deformation of the machine tool assemblies is determined by the specific machining regime. Thus, when machining an inside right angle by a ring milling cutter 18 mm in diameter with s = 400 mm/min for $R_e = 3$ mm the value of the static deformation of 60 microns was obtained (the calculated value of the normal component of the cutting force is 50 kg).

The effect of the geometric imprecision of the machine tool on the outline machining error in the general case can be estimated by the formula $\delta_{\Gamma.C} = \delta_1 \sin\alpha + \delta_2 \cos\alpha$, where δ_1 is the tolerance on the nonrectilinearity of the displacement along the X-axis; δ_2 is the colerance on the mutual nonperpendicularity of the displacements along the X and Y axes and the nonrectilinear nature of the displacement along the Y-axis; α is the slope angle of the outline to the X-axis of the machine tool. When machining a section of the outline 630 mm long at an angle of $\alpha = 45°$ and tolerances of $\delta_1 = 8.9$ microns and $\delta_2 = 29.5$ microns the value of $\delta_{\Gamma.C} = 27.22$ microns.

The investigated outline machining dimension error components are presented in Figure 4.

Resultant Machining Error. All the components presented in Figures 3 and 4 belong to the group of systematic components; therefore the value of the resultant machining error can be estimated by analytical methods. Considering that the coincidence of the maximum values of the individual errors have the random nature, let us use the method of the sum of the squares. The value of the resultant errors in this case is defined [5] as $\delta^p_\Sigma = \sqrt{\Sigma(\delta_i)^2}$ where δ_i is the ith elementary component. The values of the error in machining a square sample 250 × 250 mm in size (the position machining regime) and a circular sample 125 mm in diameter (outline machining regime) is calculated by the presented formula.

The calculated value of the resultant error in the case of positon machining in the finish cutting mode $\delta^p_{\Sigma\pi} = 55.8$ microns, and the value obtained experimentally $\delta^e_{\Sigma\pi} = 70$ microns. Correspondingly, in the case of outline machining of a circular sample in the finish cutting mode $\delta^{p}_{\Sigma k}$ = 105.2 microns, and $\delta^{e}_{\Sigma k}$ = 120 microns. The presented data indicate sufficiently close comparison of the calculated values with the experimental values.

The diagrams (see Figures 3 and 4) clearly indicate the relation of the maximum values of the machining error components generated by various elements and factors of the complex made up of the SPID system and the digital program control system. The greatest proportion of the resultant error during position machining is introduced by imprecision of the screw, play in the feed mechanism, geometric imprecision of the machine tools, the error in the part and deformation of the tool. During outline machining, along with the above-enumerated errors, dynamic and speed components of the servodrive error and deformations of the SPID system elements are introduced.

The performed analysis will permit planning of the paths of reduction of the resultant machining error. Thus, for example, the components $\delta_{\Gamma.B}$ and $\delta_{M.X}$, as was noted above, can be eliminated as a result of using a linear position sensor. Here the sensor introduced two machining error components itself: step $\delta_{\text{ш}}$ caused by the quality of its manufacture and accumulated δ_{H} caused by the error in joining the racks.

In Soviet machine tools with digital program control, linear sensors of the DLM-11 type and inductosyns are used. For the DLM-11 type sensor, the step error $\delta_{\text{ш}}$ = 5 microns. As the experience in using the sensors in heavy machine tools has demonstrated, the value of δ_{H} can fall within the limits up to 25 microns for a displacement length of 630-1250 mm. The components $\delta_{\text{ш}}$ and δ_{H} and also the variations in the machining error diagrams caused by introduction of a linear sensory are shown in Figures 3 and 4 by dased lines.

Large reserves for decreasing the machining error are available in the digital program control unit. Thus, decreasing the discreteness makes it possible significantly to reduce the errors introduced by the digital program control system itself. Moreover, under modern conditions the digital program control system can execute special algorithms [6] making it possible to compensate for the errors introduced into the systems according to Figure 2,b by modules with nonlinear and nonidentical characteristics, play of the feed mechanism and other factors.

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METALWORKING EQUIPMENT

UDC 621.941.23-529(085)

SPECIFICATIONS FOR AND DESCRIPTIONS OF NEW MACHINE TOOLS

Moscow STANKI I INSTRUMENT in Russian No 9, Sep 79 pp 30-33

The model 1B922 thread-cutting lathe (see the first page of the cover) developed and manufactured by the Srednevolzhskiy Machine Tool Building Plant (Kuybyshev) is designed for cutting short threads and preliminary turning of parts fastened in the chuck and centers, by formers in one or two passes.

The machine tool is equipped with an automatic gear box which permits turning and cutting of the threads at optimal speeds in the automatic cycle.

The hydraulic drive of the thread-cutting slide has a servovalve which offers the possibility of cutting cylindrical and bevel threads and also unloading the transverse feed chain of the cutter from the cutting force. The guides of the thread cutting slide are screwed down and quenched. The high dynamic characteristics of the thread cutting slide permit operation with increased rpm of the former drum which determines the pitch of the thread.

The feed box insures an expanded range of the number of passes of the thread cutter. The hydraulic drive is located outside the machine tool.

Technical specifications

Greatest parts diameter, mm:	
installed above the bed	420
machined above the slide	200
Greatest length of machined part, mm	500
Greatest dimensions of the cut thread, mm:	
diameter	200
length	155
depth	4(18)
Greatest displacement of the slide, mm	450
Spindle rpm (14 speeds), rpm	75-1500

Pitch of the metric thread, mm	1.5-6
Greatest No of multiples	16
Greatest angle, degrees:	
of rise of the thread spiral	15
slope of the bevel thread	7.5
Number of passes of the thread cutter per cycle for each multiple	3-64
Longitudinal feed of the slide, mm/min	5-2000
Power of the main drive, kilowatts	7.5
Overall dimensions of the machine tool, mm:	
without attachments	2750×1670×1890
with attachments	3800×2220×2050
Weight of the machine tool, kg	4800

UDC 621.914.7:621.833

The MA70F4 gear milling machine with digital programmed control designed at the ENIMS Institute and manufactured at the Stankokonstruktsiya Plant of the ENIMS Institute is designed for machining straight-tooth, spiral wheel and worm gears and gear modules by hob cutters under the conditions of centralized small-series and unit production.

The machine has mechanized adjustment. It operates in an automatic cycle with control from a five-coordinate digital program control system (number of simultaneously controlled coordinates -- 3). A series of permanent programs realizing the standard operating cycles are built into the memory of the digital program control system. These include the cycles for machining straight-tooth gear, spiral wheel and worm gears in one or two passes. The parameters of the billet and the cutter, the magnitudes of the displacements with respect to the coordinates and the machining conditions are introduced into the machining program manually from the digital program control panel.

The composition of the machine tool is vertical. The housing of the bench is stationary. All of the established displacements are realized in the tool zone with respect to the X-axis (displacement of the milling standard for variation of the distance between centers), Y-axis (displacement of the bed along the axis of the product), Z-axis (displacement of the milling carriage along the axis of the tool), W-axis (rotation of the differential), and V-axis (rotation of the mean drive).

The division chain of the machine tool has a rigid kinematic coupling; the adjustment of the mechanisms for rotation of the product and the tool and also the displacement of the tool are realized by the digital programmed control system. In the feed drives stepping motors are used with hydraulic boosters and also worm gears and screw-nut running pairs.

The establishment of the initial position of the assemblies with respect to the coordinates and the reckoning of the dimensions are accomplished by rules with verniers. The X-coordinate has the origin established by the digital programmed control system which is periodically checked using a microscope installed on the bed.

The control panel, the cooling system and the electrical equipment are taken outside the machine tool. The clamping of the basic assemblies (the standard, the tool carriage, the bed), the tool and the part in the adjustment and automatic cycles is realized by hydraulic cylinders. For convenience of installation of the cutter, an additional arm bracket installed on the slide is made folding.

The universal design of the milling slide permits gears to be cut with longitudinal feed and with axial displacement of the cutter. The mandrel with the tool is installed in the hole of a spindle with 1:20 bevel; inside the spindle there is a clamping device for fastening the mandrel.

The execution of the complete mechanized tooling up cycle on the machine tool, the absence of change gears, the use of quick-change equipment with hydraulic clamping of the part and control of standard cycles built into the memory of the digital program control system, the set of coordinates on the system panels permitted reduction of the maximum tooling up time for the machine tool to 15 minutes and brought the auxiliary time to the level of the analogous index in large-series production.

For comparison of the output capacity of the model MAjOF4 machine tool with digital programmed control with the universal gear milling machine, a straight-tooth gear was machined in two passes ($z = 48$; outside diameter of the gear $D_k = 200$ mm; gear width $B_k = 35$ mm) by a hub cutter (outside diameter of the cutter $D_{cutter} = 125$ mm; length of the cut part of the cutter $L = 63$ mm). The machining conditions are as follows: cutter rpm $n_1 = 105$ rpm and feed $s_1 = 3.6$ mm/rev (rough pass); $n_2 = 125$ rpm and $s_2 = 1$ mm/rev (finish pass). Machining time on the MA70F4 machine tool $T_M = 8$ minutes (rough pass) and $T_M = 16.5$ minutes (finish pass); total machining time $T_{m.o} = 24.5$ minutes; piece time $T_{piece} = 25.5$ minutes; auxiliary time $t_{auxiliary} = 1$ minute; preparatory-concluding time $t_{tc} = 15$ minutes. The batch of parts $N = 6$. The piece-calculation time $T_{piece\ calculation} = t_{piece} + t_{pc}/N = 28$ minutes. The norms for the machining time on the universal gear milling machine (according to the normative materials): $t_{pc} = 45$ minutes, $t_{auxiliary} = 3.7$ minutes; $T_M = 19.2$ minutes (rough pass) and $T_M = 76.8$ minutes (finish pass); $T_{M.o} = 96$ minutes; $T_{piece\ calculation} = 107.2$ minutes. Hence, the coefficient of comparative output capacity $k = 3.82$.

The precision of a gear machined on the model MA70F4 machine tool is as follows: accumulated error F_{pr} of the pitch no more than 0.03 microns; deviation f_{pt} of the average pitch no more than 0.01 microns and error $F_{\beta r}$ in tooth direction no more than 0.01 microns.

A block of gears ($z_1 = 35$; $z_2 = 40$; $B_{k1} = 25$ mm; $B_{k2} = 25$ mm) were machined in one pass on the model MA70F4 machine tool using a hob cutter ($D_{hob\ cutter}$ = = 100 mm; L = 60 mm). The machining conditions were as follows: n = 140 rpm; s = 5 mm/rev. A batch of parts N = 6 pieces was machined. The machining time was as follows: $t_{auxiliary}$ = 1 minute; t_{pc} = 15 minutes; $T_{M.o}$ = 6.4 minutes; T_{piece} = 7.4 minutes; $T_{pice\ calculation}$ = 10 minutes.

The precision of the machined block is as follows, F_{pr} no more than 0.053 microns; f_{pt} no more than 0.12 microns and $F_{\beta r}$ no more than 0.020 microns.

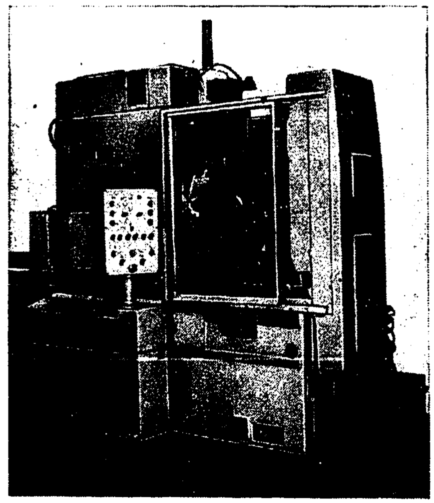
The gear milling efficiency on the model MA70F4 machine tool under the small-series production conditions is 3 to 4 times higher than the efficiency of the universal gear milling machine. The precision of machining on this machine tool corresponds to degree 6-7 according to All-Union State Standard 1643-72.

Technical Specifications

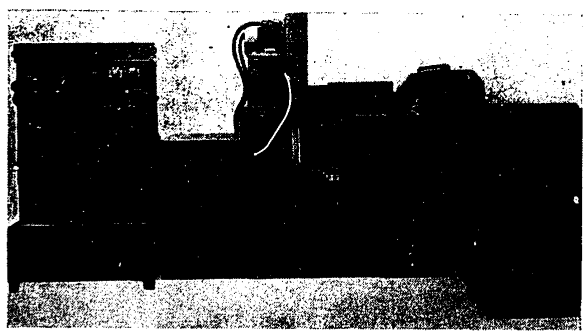
Greatest parameters of the machined product:	
diameter, mm	320
modulus, mm	6
length of tooth, mm	200
angle of inclination of teeth, deg	± 45
Least number of cut teeth	19
Bench diameter, mm	280
Spacing between bench and cutter axes, mm	45-265
Spacing from the plane of the bench to the axis of the cutter, mm	150-470
Greatest diameter of installed hob cutters, mm	160
Rpm limits of the milling spindle, rpm	50-250
Feed limits, mm/min:	
longitudinal and radial	1-100
tangential	0.4-100
Speed of fast displacements, m/min:	
longitudinal and radial	1.2
tangnetial	0.3
Overall dimensions of the machine tool without hydraulic equipment and electrical equipment (length×width×height), mm	2750×900××2250
Weight, kg	7000

UDC 621.952.5-113-111.2-52

The special horizontal one-way four-spindle semiautomatic OS-6253 finish-boring machine with increased precision designed by the Odessa SKBARS and manufactured by the Odeassa Radial Drilling Machine Tool Plant imeni V. I. Lenin is designed for semifinish and finish boring of holes under the wrist pins in automobile engine pistons.



Model MA70F4 gear milling machine with digital programmed control



Special horizontal one-way four-spindle semiautomatic model OS-6253 finish boring machine.

The semiautomatic machine is designed on the basis of the horizontal one-way model 2711P machine tool and it is equipped with four type AR-1P heads, a four-place attachment converted to hydraulic operation for installation and clamping parts and a device for loading and unloading parts.

The semifinish and finish boring are done by two cutters installed on one boring mandrel. On the machine tool automatic blowing of the base surfaces and the unloaded pistons and also removal of shavings from the operating zone by compressed air are provided.

The combination of finish boring of holes with semifinish, simultaneous machining of four pistons, maximum automation of the machining process, loading and unloading of parts and other auxiliary operations increased the output capacity (which with a use coefficient of the equipment of 0.8 is 290 pieces/hour) by more than three times by comparison with the output capacity of the finishing boring machines on which analogous machining is realized previously.

Technical specifications

Spindle rpm	4032
Number of operating feeds	2
Bench feed, mm/min:	
semifinish	480
finish	240
Distance from the spindle axis to the plane of the bench, mm	310
Distance between spindle axes of two heads, mm	200
Bench stroke, mm	300
Number of electric motors of the main drive	2
Power of the main drive electric motors, kilowatts	3
Overall dimensions of the semiautomatic machine (length×width×height), mm	2200×1000××1800
Weight (without the electridal cabinet and the complete hydraulic drive), kg	5182

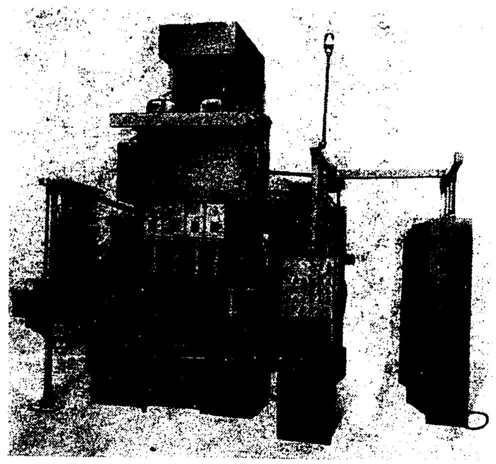
UDC 621.9.06-52:658.527

The model OS-6352 vertical four-spindle section of automatic lines designed by the Odessa SKBARS and manufactured by the Odessa Radial-Boring Machine Tool Plant imeni V. I. Lenin is designed for semifinish and finish boring of the sleeves of internal combustion engines for automobiles.

The section is equipped with four spindle heads type U15-23B. It is designed for building into an automatic line and execution of the following operations: reception of the billet and feed of it to the machine tool conveyor, completion of four machined parts, preliminary and final machining of the sleeves, unloading the machined parts to the conveyor of the automatic complex.

In the section provision is made for fine impulse adjustment of the cutting tool made of elbore; cutter feed of 2 microns per pulse. For adjustment of the cutter to the machining dimensions, a special measuring device is used.

On the section the following advanced technical designs have been realized: The application of a hydraulic system to remove the shavings, finishing of the base surfaces and feed of the cooling and lubricating liquid to the cutting zone (the bottom built into the foundation is used to collect the shavings and the cooling and lubricating liquid; the automatic centralized



Model OS-6352 vertical four-spindle section

lubrication system; complex hydraulic drives with open executions; differential hydraulic cylinder providing for an increase in speed of the fast travel of the platform to 7 m/min; upper arrangement of the electrical and hydraulic lines; functional-modular principle of constructing the electrical equipment. The output capacity of the section (142 pieces/hour with an equipment loading coefficient of 0.8) is twice the size of the output capacity of the special vertical model OS-4837 six-cylinder semiautomatic machine previously used for machining such sleeves.

Technical specifications

Spindle rpm	750
Operating feed for finish boring, mm/rev	0.08
Fast travel speed of the platform, m/min	7
Spacing between spindle axes, mm	210
Number of main drive electric motors	2
Total power of main drive electric motors, kilowatts	13.6
Overall dimensions of the section (length×width×height), mm	3890×3255××3140
Weight, tons	15

UDC 621,952.5-112-111,2-52

The high-precision model OS-6989 special horizontal two-way four-spindle semiautomatic finishing boring machine designed by the Odessa SKBARS and manufactured by the Odessa Radial-Drilling Machine Tool Plant imeni V. I. Lenin is designed for fine boring of two holes in spindle sleeves. The machine tool with two-place attachment converted to hydraulic drive is executed on the basis of the model 2712V finish boring machine and is equipped with two type AR-3V heads and two type STPu15-53V heads.

The structural design of the semiautomatic machine provides for the machining of one of the types and sizes of sleeves in lots with adjustment with respect to one of the cycles. The retooling of the semiautomatic machine for machining sleeves of another type and size reduces to adjustment of two drive belts for another head and to switching to the second operating cycle.

The structural design of the boring bar permits installation of cutters for cutting the ends. The sleeves machined on the semiautomatic machine are characterized by the following indexes: the diameter tolerance with respect to second class precision; ovalness and conicalness of the holes no more than 0.005 mm; noncoaxialness of the holes no more than 0.01 mm; surface roughness R_a = 1.25 to 2.5 microns. The output capacity of the semiautomatic machine with an equipment use coefficient of 0.8 is 7 pieces/hour.

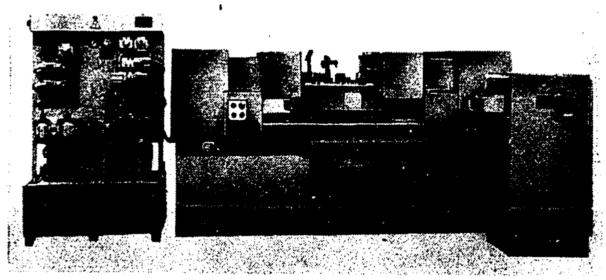
Technical Specifications

Feeding, mm/min:	
small feed mechanism	10
bench	32
Spindle rpm	955
Bench stroke, mm	393/490
Distance from the spindle axis to the plane of the bench, mm	350
Main drive electric motors	2
Power of main drive electric motors, kilowatts	3
Overall dimensions of the semiautomatic machine (length×width×height), mm	3835×2140××7200
Weight (without auxiliary equipment), kg	7200

UDC 621.957.6-52

The model 2A932 centering-resetting semiautomatic designed by the Vitesk SKB 3ShS and manufactured by the Yerevan Machine Tool Building Plant imeni F. E. Dzerzhinskiy is designed for machining center holes with simultaneous recessing of the ends from two sides on the shafts. On the semiautomatic machine (when equipped with a combination tool) it is possible dress the ends of the shafts and remove the faces. With the loading device of the model U29-532 through conveyor installed by customer request for additional payment, the semiautomatic machine can operate autonomously in the automatic mode or it can be built into an automatic line.

The structural design of the semiautomatic machine corresponds to the modern requirements of the technological nature of manufacture, operation and repair, it insures free access to all the assemblies and mechanisms for assembling and dismantling the assemblies. The rigidity and the service life of the spindle assemblies are increased as a result of the application of two-row roller bearings; the service life and repairability of the centering-recessing heads are increased. The bed of the semiautomatic machine has prismatic guides which insure high rigidity and stability of the machining precision.



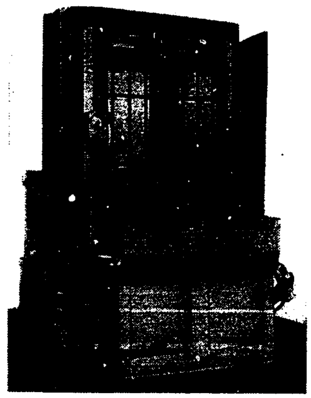
Model OS-6989 special horizontal two-way four-spindle semiautomatic finishing boring machine.

Model 2A932 semiautomatic centering-recessing two-way machine.

In the drive of the mechanism for clamping machined parts provision is made for a friction coupling for regulating the required clamping force. The bed is executed with through openings between the guides as a result of which the shavings and the cooling and lubricating fluids are easily removed from the cutting zone. The semiautomatic machine has a suspended rotating panel which insures convenience of servicing and control.

By customer request for additional payment, a device can be installed for monitoring the presence of a drill.

On the semiautomatic machine the following machining precision is provided: shifting of the center holes with respect to the outside surface of the shaft no more than 120 microns; deviation of the shaft with respect to length ±150 microns; nonperpendicularity of the ends of the shaft to its



7V76D double semiautomatic vertical broaching machine.

outside surface no more than 48 microns. Surface roughness of the machined ends of the shaft R_z = 32 microns.

Technical specifications

Parameters of the machined product, mm:	
diameter	25-100
length with manual loading	150-1000
the same with automatic loading	250
Greatest rated diameter of the installed combination tool, mm	10
Spindle rpm (10 steps; adjustment by replaceable gears), rpm	180-1600
Greatest stroke of the tail spindle, mm	95
Power of the main drive electric motor, kwt	5.5
Overall dimensions of thesemiautomatic machine (length×width×height), mm:	
with remote electric bay	3500×1200×1650
attached loading device	3500×3000×1650
Weight, kg:	
without remote electrical bay	3600
with remote electrical bay	3800
with attached loading device	4500

UDC 621.919.3-111.1-52

The model 7V76D double vertical semiautomatic broaching machine designed by the Minsk SKB PS and manufactured by the Minsk Machine Tool Building Plant imeni S. M. Kirov is designed for broaching the outside surfaces of parts of different geometric shape and size. The material of the machined parts is ferrous, nonferrous metals and alloys. The machine tool is especially effective under the conditions of mass and large-series production. The precision class of the machine tool is N.

The semiautomatic machine is the base machine tool of a range of broaching machines assimilated by the Minsk Machine Tool Plant imeni S. M. Kirov. It is built to replace the model 7B76D broaching machine and permits an increase in output capacity by 1.5 times as a result of simultaneous machining of two parts, autonomous adjustment of the length of stroke of the right and left operating carriages, independent control of the feed and withdrawal of the right and left benches, increased vibration resistance (which insures the possibility of machining parts in one pass or on higher cutting conditions and also increases the strength of the cutting tool).

The double machine tool takes up less area than two model 7B76D machine tools (for parallel operation of them) and requires less power; the expenditures on equipment and on repairs and servicing are reduced; the tooling up of the machine is simplified as a result of independent control of the right and left operating carriages and benches.

With respect to the degree of mechanization, automation, convenience of servicing and ability to be built into automatic lines, convenience of control and quality of finish, the machine tool corresponds to the requirements of industry and corresponds to the higher quality category. The nonperpendicularity of the machined side surface to the reference surface of the part is no more than 24 microns for a length of 300 mm.

Technical specifications

Rated tractive force, tons	20
Greatest stroke, mm:	
operating carriages	1250
bench	125
Width, mm:	
operating carriages	500
bench	450
Distance from the surface of the operating carriages to the end of the bench, mm	200
Speed of operating stroke (continuous regulation), m/min	1.5-13
Greatest transverse cross section of tool, mm	200×510
Power of main drive electric motor, kilowatts	30
Overall dimensions of the semiautomatic machine without work area and lift (length×width×height), mm	3550×2585××3360
Weight, tons	17.29

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CSO: 1821

METALWORKING EQUIPMENT

UDC 621.9.06-529

OPERATING EXPERIENCE USING MACHINE TOOLS WITH DIGITAL PROGRAM CONTROL

Moscow STANKI I INSTRUMENT in Russian No 9, Sep 79 pp 34-35

[Article by N. N. Zhevakin]

[Text] In March of 1979 a two-day seminar of the main specialists of the enterprises of the Ministry of Electrotechnical Industries was held at the base of the Ivanovo Machine Tool Building Production Association (ISPO). The experience of the Ivanovo Heavy Machine Tool Building Plant imeni 50th Anniversary of the USSR (IZTS) in using machine tools with digital program control was investigated.

The enterprises of the electrotechnical industry must in future years significantly increase the volume of machining without calling on additional manpower. This is will be possible only under the condition of reequipment of the production facilities with high-output equipment. The branch has a large number of machine tools with digital program control at its disposal, and the effective use of them requires study of the positive experience accumulated by the machine builders of the country.

For the IZTS, on the one hand, intense use of machine tools with digital program control in its own production is characteristic (more than 2000 nomenclatures of parts are machined on these tools; more than 50% of the total volume of the machining is done on them), and on the other hand the creation and assimilation of the production of modern machine tools with digital program control, including multiple-tool milling and boring machines, is characteristic.

In the report by director general of the ISPO V. P. Kabaidze, it was noted that the experience of the IZTS includes a number of production and social problems that are very different with respect to nature, significance and volume: from the order of arrangement of equipment with the digital program control and the organizational structure of the administration to the age of the operators working on these machine tools.

The effectiveness of using machine tools with digital program control depends on many factors, in particular, on the mass application of them:

it is expedient to buy machine tools with digital program control not one-by-one, but in lots of about 10. This is explained by the fact that the expenditures during initial operation are commensurably high by comparison with returns. The smaller the proportion of the expenditures per unit of equipment, the higher the effectiveness of using it. At the IZTS the fleet of machine tools with digital program control numbers 118 units, and it is growing with each year; in 1978 the plant did not buy a single universal machine tool.

Arrangement of the Equipment with Digital Program Control and the Structure of the Subdivisions that Operate and Maintain it. At the IZTS the machine tools with digital program control, depending on the type of operations, are arranged in four sections: lathe (for machining solids of rotation); milling-boring (including multiple tool); heavy boring; milling.

The technological programmed machining division (TOPO) has been formed which includes the production dispatch apparatus, the repair workers (the mechanical section, electronics and cranes), the process programmers, the tool designers, the service for completing and adjusting the tool, the metrologic support group, the economist-planner, and so on. The adopted organizational structure makes it possible to realize the greatest operative control.

Support with Tools. The support with tools is a very important aspect of the production process, especially when machining complex parts. Practice shows that when machining the housing of a part the machine tool uses 250-350 units of cutting tools.

At the TOPO all of the tools are concentrated in the KNIR [completion and adjustment of tools for size] section. The section (see Figure 1)[1] has more than 62,000 units of cutting tools available, that is, there are approximately 530 for each machine tool. The tools are stored in shelves.

The highly qualified tool makers and fitters adjust the tools according to a special card which is made up by a program (see Figure 2) and they sharpen the tool required for machining the given part. The machine tool operator receives the prepared set, transports it on a platform dolly (see Figure 3) to the machine tool and plugs it into the tool standard (see Figure 4). Thus, the expenditures of time by the operator on preparing the tool are minimal. Immediate return of the tool to the KNIR section on completion of machining makes it possible to achieve a high degree of use of it.

Organization of Repair. The mechanical part of the machine tools with digital program control is serviced by the fitters and repairmen, and the electronic part, by electronic specialists (basically engineers), who are combined to form an office. In the machine tools with digital program control operating at the IZTS, 37 varieties of control systems are used. For

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[1] Figures not included.

operative control of failures in the electronic part of the machine tools the office has developed a warning system with automatic accounting for the idle time of the machine tools -- Takt-1. Its introduction made it possible to reduce the idle time caused by failures of the electronic part by 2 or 3 times.

The operation and maintenance of machine tools with digital program control at the ISPO is combined with the creation and production of new models of such machine tools. The first models, as a rule, remain at the plant. This makes it possible to discover structural deficiencies and immediately improve the structural design of the manufactured machine tools and control systems in the best way during operation.

Development and Instruction of Programs. The engineer program, using a computer, calculates the technological process of machining, punches out a punch data and personally performs test machining of the first part. After correction and new tests, the fully developed technological process is put into production. In one month the programmer develops 7 or 8 programs for parts of medium complexity.

Wages on Machine Tools with Digital Program Control. At the ISPO, a wage system has been developed and tested for a number of years for the labor of all categories of TOPO workers. A defined percentage of the bonuses reckoned for fulfillment and overfulfillment of the assignments. For the calculation a productivity level coefficient is used which is defined as the ratio of the operative time to the calendar time of operation of the machine tool. The level coefficient is planned, beginning with objective data: the degree to which the machine tool has been assimilated, the equipment of it with tools and attachments, the degree of complexity of machining, and so on. A bonus in the amount of 30% of the fixed wage is reckoned for achievement of a defined productivity level coefficient. For exceeding the given level coefficient for every 0.01, another 5% is reckoned, but no more than 20% in a month.

The workers also receive from 5 to 10% of the fixed wage for independent adjustment of the machine tools. The size of the bonus is fixed for the auxiliary workers on time rate depending on the fulfillment of the assignment by the basic workers. The bonus of the repair services depends on the idle time of the machine tools. The engineering and technical workers receive bonuses of up to 30% of the fixed salary for fulfillment of the production program by the sections with a planned productivity of level.

The ISPO has adopted its own criterion for determining the effectiveness of utilizing equipment with digital program control. The defining indexes the coefficient expressing the ratio of the total work time of the machine tool to the calendar work time and characterizing the level of organization of production.

"The experience of the Ivanovo machine tool builders," chief technologist of the IZPS, comrade B. A. Chekalov said in his report, "permits a number of generalizing conclusions to be drawn with respect to the use of machine tools with digital program control. The machine tools with digital program control insure high, stable quality of the machined parts along with a sharp increase in productivity. The concentration of operations of such machine tools permits the exclusion of numerous steps of transporting the parts from the technological process, a significant reduction in the volume of work for the dispatch services and the machining cycle. The amount of equipment for the machine tools with digital program control is significantly less than for ordinary machine tools."

The application of machine tools with digital program control is an incentive for the creation of new types of machining, for example, milling of planes by cutters made of elbore-R instead of grinding, and so on. These machine tools also are influencing the billeting processes. For example, by the traditional process many holes in the walls of cast parts are obtained when casting using cores and then boring. However, when machining such parts on machine tools with digital program control frequently it is faster and more reliable to bore the hole entirely by a core drill. This makes it possible to reduce the volume of molding operations and simplify casting.

One of the means of improving the effectiveness of machine tools with digital program control is also the application of light alloys which promotes a sharp increase in cutting speeds and an increase in the strength of the tools by 6-7 times.

The basic requirements on the technological nature of the part have appeared, the primary criterion for which is lowering the labor consumption of the machining process. The designer must make maximum use of standardized designs. For example, in one part it is possible to provide for a number of holes of several close diameters; for each hole diameter a special tools is required. However, it is more expedient to use an average diameter for all of the holes. This standardization is successfully used in the IZTS practice. Finally, the training of the machine tool operator is significantly simplified. In order to train a qualified universal lathe operator it takes 3 to 5 years; the training of an operator for a machine tool with digital program control takes 3 to 5 months. The IZTS practice shows that the young people are more inclined to go to machine tools with digital program control because working on complex modern equipment has prestige value.

The difficulties arising when introducing machine tools with digital program control include large initial expenditures, absence of a universal reliable control system, absence of a universal adjustable set of tools.

The head of the TOPO, comrade V. Ya. Maksimov told about the principles of arrangement of the programmed equipment, the interaction of all the services in order to develop an optimal version of the process (in particular, reduce the number of machining operations and the number of tools), the organization of repair operations. At the IZTS, the practice of creating complex repair brigades when it is necessary to repair both the mechanical and electronic parts of the machine tool has become widespread.

Independently of the fact that the fleet of machine tools with digital program control is growing annually, there is constant work on modifying the previously acquired machine tool, in particular the development and installation of assemblies that are identical for the entire group of machine tools, a united punch tape, tools, and so on.

Chief engineer of Ivanovo Special Design Office for Machine Tools, comrade Yu. V. Maslovskiy familiarized the participants in the seminar with the technical specifications of the horizontal boring and multiple tools milling and boring machines with digital program control manufactured by the ISPO.

The participants in the seminar were offered the possibility of familiarization with the practical experience in using equipment with digital program control. They inspected the sections, the TOPO services, and they received exhaustive information with respect to the various problems of operating and maintaining machine tools with digital program control.

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CSO: 1821

METALWORKING EQUIPMENT UDC [621.9.06:621.833]002.2

GEAR CUTTERS FOR UNTEMPERED CYLINDRICAL GEAR WHEELS

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 79 pp 1-2

[Article by E. K. Filippov: "New Trends in the Production of Gear Cutters for Manufacturing Untempered Cylindrical Gear Wheels"]

[Text] In industry, untempered gear wheels are manufactured under small-series, series, large-series, and mass production conditions. When manufacturing average-size gear wheels their conditional assignment to the indicated types of production depends on the size of the order to be produced: 2-20 items-individual and small series; 20-200 items-series; more than 300 items-large series.

Gear-wheel production under large-series and mass production conditions accounts for approximately 60 percent of their total production and the number of gear cutters used for this is about one third of the total inventory of such equipment. The parameters of gear hobbers when working in one shift are presented below as a function of the type of production.

Type of Production	Small Series	Medium Series	Large Series
Machine operating time for the cutter, %	25	41	75
Cutter set-up and control time, %	39	31	10
Management time, %	36	28	15
Productivity, units	4	17	92

The universality of the gear cutters which are being produced is a distinctive trait. Special machine tools are created on the basis of the universal tools for large series and mass production of gear wheels. The semi-automatic work cycle of gear cutters permits multi-unit servicing (one worker services 4-8 instruments depending on the type of production).

It is possible to increase the efficiency of gear wheel production by increasing the productivity of the cutters working with traditional methods and by creating new highly productive cutters, as well as by increasing the output of special gear cutters. Intensification of the cutting modes (with a simultaneous increase in the level to which loading is automated) has the greatest effect on increasing productivity of gear cutting under large series and mass production conditions. Under small series and series production conditions, intensification of the cutting modes does not increase the processing productivity because of an increase in set-up and control time for the cutters and the reduction in the number of cutters serviced by one worker.

The basic trends for increasing productivity of gear cutting are presented below as a function of the batch size to be produced.

Individual and small series production. Reducing the set-up and control time for the cutters (with a simultaneous intensification of the cutting modes) by creating cutters with ChPU [digital program control]; using easily detachable equipment for mounting the item and replacing the cutting tool; automation of cutter loading on the basis of universal loaders.

Series production. Reducing the set-up and control time for the cutters (with simultaneous intensification of the cutting modes) by creating universal gear cutters with adjustment being mechanized to a great extent on the basis of electronic control systems; automation of loading on the basis of quickly readjustable units.

Large series and mass production. Reducing the machine time for processing by using high-speed and heavy-duty cutting on the basis of production gear hobbers; automation of loading and reducing the time for adjustments when producing average size wheels; the development of new processing methods oriented to the individual gear wheels or to a group of wheels.

Proceeding from what has been stated, the following structure for gear cutter production is proposed: 1) Universal cutters with digital program control (for individual and small series production) which insure short time for repeated set up and control of the cutters' work cycle; 2) Universal cutters (for series production) with automated and mechanized set-up (on the basis of electronic systems) and automated loading (on the basis of specialized, quickly readjustable loading and transport systems); 3) Automatic production machinery (for large series and mass production) with a minimal readjustment capability, equipped with loaders (for 4-8 hours of continuous operation) and easily installable on automatic lines and sectors.

Basic design decisions for cutters with the proposed structure. Reduction in idle time by reducing auxiliary time and set-up time may be accomplished using the digital program control systems, the use of which automates set up, control of the work cycle, positioning and control of the cutting mode. The use of digital program control systems fundamentally changes the kinematics and significantly simplifies the design of the cutter, broadens its industrial capabilities and improves working conditions. The cutters' set up time is reduced to 1/6-1/10 of the present level. Equipping the cutters with easily removable equipment for fastening the part and the cutting tool also reduces the auxiliary time.

The indicated measures will permit us to increase productivity of gear cutters (under small series production conditions) by a factor of 2-3.

A model MA70F4 experimental prototype of a gear hobber with digital program control has been produced by the ENIMS [Order of the Red Banner Experimental Scientific Research Institute of Machine Tools] and blueprints for series productions have been developed based on results from its testing.

Increasing the productivity within the group of universal cutters for series production will be achieved by using digital display devices for adjustment displacements and cyclical control systems for the cutting mode and by using mechanized clamps. The most important reserve for increasing the productivity of this group of cutters is to equip them with universal readjustable loaders. As a result of the ennumerated improvements, the productivity of the universal cutters will be increased by a factor of approximately 1.5 for series production.

The creation of new automatic production machinery will permit us to insure large series and mass production with highly productive cutters. The increase in productivity of this group of cutters is being achieved by equipping them with special automatic devices (easily incorporated into automatic lines and sectors), by increasing the capabilities and the rigorousness of the cutters (for the possibility of using highly productive cutting tools and intensification of the cutting modes).

Taking into consideration the state of the gear hobbing process, the prospects for its development as well as the requirements for large series and mass production, the ENIMS developed an engineering task covering a gamut of production gear hobbers, with the largest processing diameter being 125-800 millimeters. Hobbers operating with hard alloy hobbing cutters and hobbers for machining pinion-and-shaft units are being made on the basis of the basic version of these hobbers.

The method for gear sharpening which is presently being developed is one of the methods of heavy duty hobbing using a multi-start cutting tool. Machining is done by continuous division, the axes of the cutting tool and the article intersect. One characteristic of the method is the fact that the cutting tool profile is calculated as a function of the parameters of the individual item (the modulus, the number of teeth, the angle of the profile and the spiral).

Research was performed on the cutting dynamics, the structure and the accuracy of the kinematic links of the cutters for gear sharpening as well as the geometry of the cutting tool, its accuracy and endurability. Model 5382 and MA 5382 cutters with a productivity twice that of gear hobbers were designed and produced by the ENIMS on the basis of the research which was performed.

A typical engineering design for tooth machining in mass production is composed of two operations: removal of metal from the grooves between the teeth (gear hobbing or gear shaping) and finishing the teeth to the necessary precision (shaving).

Shaving has become widespread due to the high productivity, the simple equipment and cutting tool and the possibility for automating the process. Relatively small metal removal during the machining process is a feature of shaving. In this case, rigid requirements for the size and shape of allowances, accuracy and roughness are required for the surface of the blank's tooth, a fact which does not permit the cutting modes to be intensified to the maximum extent during gear hobbing and gear cutting and completely excludes the use of highly productive gear machining methods (contoured gear cutting, heavy duty hobbing with multi-start hobbers, hot rolling etc.) which do not assure the necessary machining accuracy during shaving.

Single-edge shaving with the cutting tool (in the form of a gear wheel), which is joined to the article being machined by a rigid kinematic bond, is a further development of shaving. Single-edge shaving has the following advantages in comparison with ordinary shaving: In the case of equal productivity the effect of the accuracy of the blank on the final accuracy of the item is excluded because of the presence of the rigid kinematic bond between the item and the cutting edge; the magnitude of the allowance which is being taken off grows by a factor of 2-3.

Incorporation of single-edge shaving can fundamentally change the production process for manufacturing gear wheels in mass production since here the traditional preliminary operations of tooth cutting (gear hobbing and gear cutting) may be replaced by more productive ones. Presently experimental work on the development of a single-edge shaving process are completed at the ENIMS and blueprints for an experimental prototype cutter have been developed.

The creation and incorporation of gear cutters with the proposed composition will permit us to increase gear machining productivity by a factor of 1.8-2.

[143-9194]

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DIGITAL-PROGRAM CONTOUR POLISHING

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 79 pp 5-8

[Article by Yu. S. Reybakh: "Specifics of Contour Polishing Using Digital Program Control"]

[Text] The relative significance of automated machinery is continually growing in modern machine building, and the requirements for their accuracy and their endurability are increasing. The use of cams and master forms of various types as well as stamps, stators for special pumps and other items with hardened surfaces of high precision which require polishing is expanding because of this. The technological classification of the complex items enumerated (conditionally called "cams") is shown in Figure 1 and in Table 1.

Aside from the traditional profiling and profile polishing machines, contour polishers with digital program control may be used for machining such items. Their use insures that modern means of computer technology will be efficiently brought into the manufacturing process and that operations will be executed which are not characteristic of standard polishers; this frequently includes even operations which were formerly not executable (taking the constant wear of the polishing wheel into consideration, calculation of equidistant points, varying the machining speed on individual sections, etc).

A model MA396F3 semiautomatic contour polisher with digital program control has been developed and is being produced on a series scale at the ENIMS [Order of the Red Banner of Labor Experimental Scientific Research Institute of Machine Tools]. The design features are described in [1]. It is intended for machining flat cams characterizable by the following features: Material--alloyed steels, hardened or nitrided (HRC 52-63), special alloys or cast iron (in the latter instance, the cams' working surface is chilled); sometimes coatings are applied to the cam surface containing nickel, carbides, or silicon, which are distinct because of their great hardness and wear resistance.

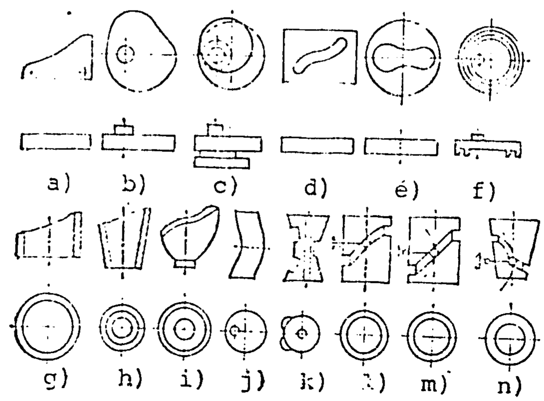

Figure 1. Varieties of cams.

The required accuracy of the form is 0.01-0.05 mm; the accuracy of the dimensions is 0.02-0.05 mm, and the roughness of the surface R_a equals 0.16-0.32 microns. On most cams the permissable nonperpendicularity of the generatrixes of the working profile to one of the base faces (not more than 0.01 mm) and the nonrectilinearity of the generatrix forms is regulated.

The profile being machined is usually specified in polar or Cartesian coordinates. Occasionally it is executed in the form of an Archimedean spiral or it must conform to the law of motion of the cam mechanism's follower. It is necessary to specify the profile in Cartesian coordinates when compiling such a machining program.

When machining complex surfaces on contour polishers with digital program control, the position of the blank on the polisher tables should be unambiguously adjusted to the program. This is insured by the specific orientation of an adapter relative to the central T-shape groove and the central opening in the polisher table (the axis of the opening coincides with the initial position, i.e. with the beginning of the coordinates).

The adapter is universal and contains one replacement part which is designed and prepared as applicable for a specific instance. The blank is based in the verticle sense along one of the faces and in the angular sense along two cylindrical surfaces (two studs or a fitting hole and a stud or pin can serve as the bases). Here clearance and misalignments of the base surfaces assert a noticeable influence on the machining accuracy. The classification and the effect on the individual factors on deviations of the form and dimensions of the items are shown in Table 2. The relative importance of each of the indicated factors as a part of the total machining error varies as a function of specific conditions; however the following rough characterization allowing for these factors may be given.

Table 1.

Тип 1	Подтип 2	Вид 3	Эскиз по рис. 1 4	Число управляемых координат (без участа правки круга) 5	Управляемые координаты 6	Возможность работы с осцилляцией 7
8 Плоские	9 Открытые	10 Призматические	13 а		X; Y	17 Есть
		11 Дисковые	14 б		X; Y 16 или X; W	
		12 Блочные	15 в	2	X; Y 16 или X; W	
	19 Полуоткрытые	10 Призматические	22 г	2	X; Y	»
		Кольцевые	23 д		X; Y 16 или X; W	
	20 Закрытые	21 Пазовые	24 е	2	X; Y 16 или X; W	18 Нет
33 Пространственные	9 Открытые	25 Цилиндрические торцовые	29 ж	2	X; W	17 Есть
		26 Конические торцовые	30 з	3	X; Y; W	18 Нет
		27 Сферические торцовые	31 и	3	X; Y; W	»
		28 Коноидные	32 к	4	X; Y; Z; W	»
	19 Полуоткрытые	34 Глобоидные	35 л	2	W; W'	»
	20 Закрытые	36 Цилиндрические с поступательно перемещающимися толкателем	37 м	2	X; W	»
		38 То же, с качающимся толкателем	39 н	3	X; Y; W	»
		40 Прочие	41 о	4	X; Y; W; Z	»

42 Примечание. W'—дополнительная координата (качательное движение относительно центра окружности, образующей глобоидную поверхность)

Key:

1. Type
2. Subtype
3. Kind
4. Sketch in Figure 1
5. Number of controlled coordinates (not considering circle correction)
6. Controlled coordinates
7. Possibility of operation with oscillation
8. Flat
9. Open
10. Prismatic
11. Disc
12. Block
13. A
14. B
15. C
16. Or
17. Yes

[Key continued on following page]

18. No
19. Semi-enclosed
20. Closed
21. Slotted
22. D
23. E
24. F
25. Cylindrical face
26. Conical face
27. Spherical face
28. Conoid
29. G
30. H
31. I
32. J
33. Three dimensional
34. Globoid
35. K
36. Cylindrical forward-moving follower
37. L
38. Cylindrical with a rocking follower
39. M
40. Others
41. N
42. NOTE: W' is an additional coordinate (rocking movement relative to the center of the periphery forming a globoidal surface)

The errors in basing the item have been examined in detail in [2]; although they are extremely important for the overall result, they are not specific for polishers with digital program control and are manifested on other machine tools (profilers, tools with kinamatic shaping) when milling profiled surfaces. It was shown in [3] that the dominant forming errors are associated with errors in table positioning. These positioning errors are decisively effected by the pitch accuracy of the guide screws producing coordinate displacements in the XY plane. Given quality production of the tool, the positioning error is roughly determined by the geometric sum of the errors in pitch along the X and Y axes on the working sections of the guide screws. In particular it follows from this that when machining the interior and exterior cylindrical surfaces of equal diameter, the machining accuracy is lower in the latter instance, as a rule. This is explained by the fact that during contour polishing on an exterior cylindrical surface the length of the working sections of the guide screws is greater; the accumulation of pitch error which is converted to machining error is also correspondingly greater. For average parts, the error caused by table positioning does not usually exceed 5-7 microns.

Table 2

Factor	Error caused by the given factor, microns. In Size	In profile Shape	Means for correcting the error.
Basing the item	10-15	10-15	More careful execution of the production basis.
Table positioning	5-7	5-7	Introduction of compensation for systematic errors into the digital program control memory.
Approximation of curves	--	1-2	Reducing discreteness.
Variability of the radius of a profile curve	5	5	Programming the machining for constant contour speed.
Reorientation of the polisher units	--	3-4	Reduction of clearances; the use of preliminary tension in the guides.
Heat deformations of the polishers	--	4-6	Installation of refrigerating units and temperature stabilizers.
Positioning of the diamond for trueing	2-3	--	Introduction of compensation for cyclical error of the guide screw into the memory of the digital program control system.
Diamond wear	1	--	Changing the tuning of the decade change over switches.
Dynamic effect of the polisher's feed drive system.	--	--	Use of self breaking devices in the drive system.

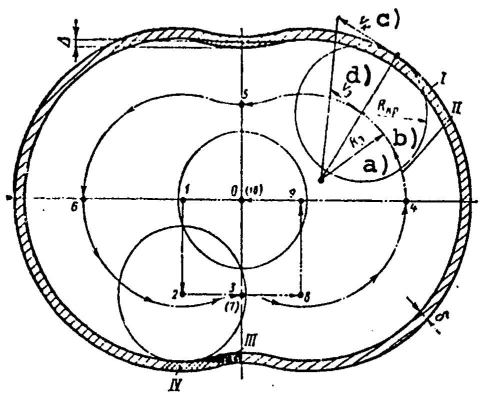

Figure 2. Diagram for machining an internal epitrochoidal surface: I--contour of the item; II--equidistant contour; III--entry zone; IV--exit zone; δ --margin; Δ increase in the small axis of the opening; 1-10 sequence of relative movements of the wheel and the item.

Key:

a) R_e
b) R_w
c) v_i
d) v_e

When preparing the machining program, the specified curves are approximated by circumferential arcs and sections of straight lines so that the error of approximation, i.e. the deviation of the profile which is being realized from that which was specified does not exceed the following fraction: 1/8-1/10 of the tolerance for profile accuracy (1-2 microns for practical purposes). This condition is easily satisfied given a discreet motion interval of 1 micron. Machine preparation of the programs permits its performance to be rapidly evaluated and corrected.

As experience in using polishers of the type being examined has shown, the error of approximation is an inconsequential part of the total forming error. Moreover, the form itself of the profile of a complex surface, particularly the surface of a variable and alternating curve, exerts considerable influence on forming accuracy during polishing. Let us examine, as an example, machining the inner surface of the stator of a rotary piston engine described by an epitrochoid (Figure 2). If we designate the instantaneous radius of the curve of the equidistant profile R_e and the radius of the polishing wheel R_w we may express a dependence between the translational velocities v_i and v_e on the contour of the item and on the equidistant contour as $v_i = v_e (1 \pm R_w/R_e)$. Here R_w is smaller than R_e and the sign depends on the shape of the sector of the curve (concave or convex). It is clear from this equation that if when moving from one sector to another v_e is constant, v_i is variable and the arc of contact between the wheel and the item is also variable along the length. The latter is expressed in the continuous change of the specific polishing force and in a change in the intensity with which the material left for allowance is removed, causing, in the final analysis, a change in the form of the profile being machined. In sections where the arc of contact between the wheel and the item is small, the specific polishing force is great resulting in a greater removal of metal in this zone and being expressed, as an example, in an increase in Δ (cf. Figure 2) of the small axis of the opening as compared with the assigned value.

Digital program control capabilities permit us to minimize these errors in form, maintaining v_i constant by varying the programmed speed v_e as a function of the form of the given curve section, i.e. by changing the magnitude of feed in specific blocks of the program. Modern capabilities of machine programming permit us to solve this problem quickly and simply. However, changes in the arc of contact between the item and the wheel cause the polishing wheel and mandrel to be moved away from the surface, a phenomenon varying in magnitude. This fact does not permit us to eliminate totally the error being examined, it remaining at a level of approximately 5 microns. It is possible to eliminate this error either by a lengthier dwelling (which however, prolongs the cycle and lowers productivity) or by the use of a self-correcting control (which is most promising).

Errors associated with <u>thermal deformations</u> and deviations of the vertical support columns as well as with <u>reorientation</u> of the polisher chuck when there are oscillations along the vertical guides do not exert a noticeable effect on the form of the profile itself, causing only aperpendicularity of the generatrixes to the base face. With the length of the full run being 360 mm., the change in chuck position does not exceed the clearance in the guides (i.e. about 0.02 mm.) which, when calculated on the basis of a cam height of up to 80 mm., corresponds to aperpendicularity within the range 4-6 microns.

<u>Diamond positioning errors</u> (the coordinate U) are caused by cyclical and accumulated errors of the instrument guide screw for correcting the wheel. These screws are usually short (about 100 mm.), and the given errors do not exceed 2-3 microns, influencing only the size of the item.

<u>Errors associated with diamond wear</u> are not considered by the digital program control system nor are they corrected. The effect of this factor is also seen only on the accuracy of the dimensions of the item. Wear does not exceed 0.005 mm. according to observations during a working day. Its effect may be totally eliminated by changing the adjustment of the decade change-over switches which determine the wheel's base radius R_b [1]. A change in the dimensions of the items as noted by the operator is a signal that this should be done.

Errors associated with the dynamics of the electrohydraulic step-type feed drive are evaluated by the magnitude of the chamfering radius of the vertex of the right angle formed on the item when feed is stopped along one of the coordinate axes and movement along the other is begun. This error was evaluated in the polisher's design stage, for which machining conditions were varied as they were being modeled on an analog computer. It was established by testing on the grinder that at v_i approximately equal to 100 mm. per minute and with self-breaking worm-and-worm wheels this error does not exceed 2-3 microns.

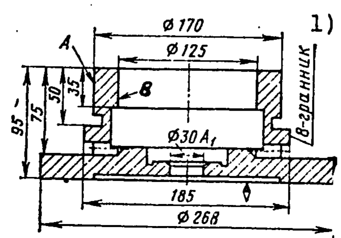

Figure 3. Reference Sample.

Key:
1) Octahedron

Evaluation of the true effect of the set of aforementioned factors on the form of the item is a complex task, and it requires special measuring devices (coordinate measuring devices with automatic records or with computer print-out of the results). Polishing a reference part (Figure 3) containing concentric outside A and inside B cylindrical surfaces and an octahedron is adequate enough to test the grinders while in operation. All of these surfaces are easily monitored using traditional methods. The results from measuring the reference part after machining permits us to judge the quality of the grinder's guides, their mutual perpendicularity and the accuracy of linear and circular interporlations. Since the profile is approximated by segments of straight lines and arcs of curves, this type of universaltest is usually adequate. The prescribed and the actual machining accuracy of the surfaces of a reference part are shown in Table 3 (data on the actual accuracy are selected at random based on measuring records).

In writing a machining program, it is necessary to take into consideration the fact that computation time for the approximated equidistant surface is proportional to the radius of displacement R_d [1]. Since the digital program control system makes computations for the step following the one being executed in a given instant the following conditions should be observed: $T_{a_{i+1}} + T_{c_{i+1}} \leqslant T_{e_i}$ where $T_{a_{i+1}}$ and $T_{c_{i+1}}$ are the access time and the computation time of the equidistant points in the following (i+1) step of the program (usually $T_{a_{i+1}}$ is approximately 0.07 seconds; $T_{c_{i+1}}$ equals approximately 1.5 seconds); T_{e_i} is the execution time of the previous (the i-th) step. Not observing this condition results in a feeding stopage and, as a result, to the appearance of markings on the profile of the item.

Table 3.

Surfaces being tested	Object being monitored	Value, microns: Acceptable	Value, microns: Actual, Average
Cylindrical (outer A and inner B)	Out-of-roundness	20	16
	Waviness	10	6
	Arectilinearity of the generatrix	5	3
	Aperpendicularity of the generatrix to the base plane	10	2-8
	Deviation from that prescribed	± 10	± 10
	Roughness R_a	0.32	0.32
Planes (sides of an octahedron)	Arectilinearity	10	2-3
	Waviness	10	4-6
	Aperpendicularity and aparallelism of the faces (on the entire length)	10	2-5
	Roughness R_a	0.16	0.16

Troubles arise when machining highly flatened parts of curves were the value of R_d is great and approaches the maximum radius of interprolation permitted by the digital program control system (500 mm.). Measures are being taken to improve the auger rhythm and to reduce the computation time for the equidistant to eliminate this shortcoming.

The site and the means by which the first cuts are made into the item are also of interest for reducing the forming errors. The best results are obtained by an incision along a tangent to the profile being machined (cf. Figure 2) which permits the load to be smoothly increased from zero to the rated value on each pass and then to be decreased from the rated value to zero upon exiting. This method of incision prevents the formation of lines on the profile which occur when cutting in perpendicular to the surface.

Machining surfaces defined by closed circles with the feed motion being reversed requires a clearance-free reversing to insure the prescribed form of the curve. This task was resolved by using worm-and-worm gear sets with multipitch worm gears in the feed drives [1]. However, total liquidation of the lateral clearance causes irregularities in the drive operation and is unadvisable from an engineering standpoint. Therefore, during assembly, a small (about 0.02 mm.) residual lateral clearance is specified in the worm-and-worm gear units, and it is further reduced in the guide screw-nut assembly so that only a part of the clearance, approximately 5-7 microns, actually effects the error of the form. This clearance may be further corrected if its magnitude is fixed for each of the coordinate axes of the grinder on the appropriate decade change-over switches of the digital program control unit's correction board. The required number of pulses is also issued for displacement of the table (until the start of the forming movement).

The correction board offers considerable conveniences and insures the necessary flexibility of control applicable to each individual machining instance. The decade change-over switches permit the structure of the machining cycle to be changed. This is necessary since multipass polishing (up to 5 passes) is possible on this machine using a single program. Thus, on each pass it is possible to assign various quantities of the allowance material to be removed, change the feed (from 110 to 10 percent with regard to the perpendicular prescribed by the program), the oscillation mode, and the dwelling mode as well as the number of passes. The very same change-over switches make it possible to vary the correction depth, to implement zero displacement, to select and change the base radius R_b of the cutting tool etc.

The following procedure may be recommended for machining cams from hardened steels using abrasive wheels 80-120 mm. in diameter and having a ceramic binder: v_i equals 115 mm./minute on the first pass with a subsequent reduction by 20-30 percent on each pass; the material left as allowance, to be removed during the first four passes, is 0.15; 0.05; 0.01 and 0.005 mm.; the fifth pass is dwelling; oscillation frequency is 30-80 two-way per minute; the correction depth is 0.02 mm. Cutting fluid consumption of 90 liters per minute (of a 4-percent aqueous solution of triethanolamine) is provided by the polisher's pumps.

Using the polisher in a number of machine building plants has permitted us to accumulate certain engineering experience. Thus, at the Moscow Machine Tool Building Plant imeni Sergo Ordzhonikidze, crescent-shaped cams (15-20 mm. high) for automatic lathes are polished in groups of 4-5 units. This has permitted the productivity to be substantially increased and manual labor to be entirely eliminated. Good results have been obtained in manufacturing complete punch-and-die sets in tool stamping production at the Moscow Motor Vehicle Plant imeni the Leningrad Komsomol. Measurements have shown that the clearance between the die and the punch does not exceed 0.01 mm. around the entire perimeter.

Special centering setup for the machine for machining bodies of revolution with a curvilinear generatrix defined by an exponent is being used at the

All-union Scientific Research Institute of Piping (Dnepropetrovsk). The particular setup has permitted them to achieve the required profile accuracy (0.01-0.03 mm.) and insure the prescribed direction for the machining track at the Zhitomir Automatic Machine Tool Plant, grooving cams are being machined in a polish-by-stops mode (without oscillations); profile accuracy is 0.02 mm.

Coordinate polishing of round openings is also possible on the polisher. In this case, the accuracy of the opening coordinates is 5-8 microns and the out-of-roundness on a 120 mm. diameter is within the range 0.01-0.015 mm.

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OPERATION OF DIGITAL-PROGRAM LATHES STUDIED

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 79 pp 17-18

[Article by V. I. Skvortsov, I. N. Sysoyev, G. S. Dzhavakhov]

[Text] The work of three models of lathes with digital program control was studied under production conditions by the Ryazanskiy machine tool plant: a centering model (A), a chucking model (B), and a semi-automatic lathe (C), with the diameter of the item being machined being 630, 630 and 500 mm. respectively (above the bed).

The lathes' operation was observed by a specially created complex group of qualified specialists, mechanical engineers, computer technology engineers and repairmen well acquainted with the design of the machine tools and digital program control units being studied and with the production processes for manufacturing the lathes, as well. Lathes were monitored at those plants where they are used adequately intensively. Eighteen lathes were under observation (including two type A lathes, seven type B and nine type C) at seven plants. The research methodology was developed taking into consideration data from the Experimental Scientific Research Institute of Machine Tools [1]. The values for reliability indices were determined as a result of the research.

Full operating time of the lathe (the reliability indicator), i.e. the average time of normal operation

$$T = \frac{1}{m} \sum_{i=1}^{n} t_i$$

where t_i is the operating time of the i-th lathe during the observation period; N is the number of lathes under observation; m is the total number of failures (including interruptions, i.e. self-clearing failures) of the N lathes (only independent failures were taken into consideration; operational failures and failures of the cutting tool were not taken into consideration). By operating time of the lathe with digital program control we mean the total duration of the lathe's operation following the control programs for a given period of time.

Average restart time (the maintainability index), i.e. the average time of forced unscheduled idle time for the lathe caused by searching for and eliminating a single failure:

$$T_r = \frac{1}{m} \sum_{i=1}^{m} t_{rj}$$

where t_{rj} is the time wasted on detecting, searching out the cause, and eliminating the results of the j-th failure of the lathe (the time waiting for repair is not included here).

The specific duration for restarting (a complex reliability index), i.e. the time wasted to detect failures and eliminate their causes (end results) taken over a unit of normal work time:

$$R = T_r/T$$

The magnitude of R may be expressed as the restart time (the idle time for the lathe in unplanned repair, taken over 100 hours of lathe operation following controlling programs). The specific duration of restarting is functionally associated with an availability quotient K_a, i.e. the probability that the lathe will be functional at an arbitrary instant of time within intervals between planned maintenance events:

$$K_a = T/(T + T_r) = 1/1 + r)$$

The quotient of technical utilization of the lathe (a complex reliability indicator, i.e. the ratio of the total operating time of the lathe for certain periods of use to the sum of this operating time and the total of all down time caused by maintenance repair for the same period:

$$K_T = \sum_{i=1}^{N} t_i / \left(\sum_{i=1}^{N} t_i + \sum_{i=1}^{M} t_{rj} + \sum_{i=1}^{N} t_{di} + \sum_{i=1}^{N} t_{mi} \right),$$

Where t_{di} is the total down time of the i-th lathe in planned repair during the observation; t_{mi} is the total down time of the i-th lathe associated with its maintenance for the observation period.

The values of the given reliability indices for the lathes in relative values are given below (the indices of type A lathes are taken as unity):

Lathe Model	A	B	C
T	1	0.93	0.96
T_r	1	2.81	2.50
R	1	3.01	2.61
K_t	1	0.82	0.83

Table A

Values of the reliability indices for the individual units of the lathes (the digital program control device (DPCD), the mechanical units and the hydraulic and electrical equipment) are given in Table 1 (also in relative values). The reliability indices of the DPCD of type A lathes are taken as unity.

Table 1

Unit	Lathe Model	Reliability indices T	T_r	R
DPCD	A	1	1	1
	B	0.75	2.13	2.75
	C	0.43	2.86	6.50
Mechanical Units	A	1	0.80	0.75
	B	0.92	5.18	5.50
	C	1.66	4.65	2.75
Electrical Equipment	A	2.0	2.29	1.0
	B	4.1	2.86	0.5
	C	7.2	1.23	0.15
Hydraulic Equipment	A	1.0	1.29	1.25
	B	2.73	3.60	3.23
	C	1.80	3.23	1.75

To evaluate the values for the reliability indices presented above, the distribution of breakdowns m detected during the observation period between the basic units of the lathes of each model and the distribution of the duration of down time t due to the failures are shown in Table 2 (both indices are given in parts of the total number of breakdowns and of the total duration of down time respectively). It may be seen from Table 2 that the completing items (the DPCD and the hydraulic equipment) are the least reliable elements. Thus, on type C lathes 82.3 percent of the total number of breakdowns and 73 percent of the down time period due to technical causes fall to the completing items.

Table 2

Unit	m, % for lathes A	B	C	t, % for lathes A	B	C
DPCD	28.6	35.5	64.6	22.5	21.6	60
Mechanical units	28.6	45.1	17.7	17.9	63.1	27
Electrical equipment	14.3	6.5	3.8	25.6	5.3	1
Hydraulic equipment	28.5	12.9	13.9	34.0	10.0	12
Total	100	100	100	100	100	100

To reveal the inadequately reliable elements from among the mechanical units and the hydraulic equipment, the distribution of the number of their failures and the down time period was analyzed (Table 3). This permitted us to plan and then realize experimental-design and experimental-research operations on the basis of which new design decisions were proposed and incorporated. These decisions improve the reliability of the units. As a result, the reliability of the automatic gear box increased by a factor of 9, that of the tool holder by a factor of 6 and that of the pneumatic chuck by a factor of 8. The anticipated increase in the service life of ball-type screw gages (due to the introduction of a new design for the protective devices) should be by a factor greater than 4.

Table 3

Units	Elements of the units	m, % for lathes A	B	C	t, % for lathes A	B	C
Mechanical	Automatic gear box	-	35.3	7.7	-	66.2	14.0
	Ball-type screw gages	-	5.9	-	-	12.0	-
	Pneumatic chuck	-	11.8	30.8	-	3.8	57.5
	Tool holder or tool magazine	50	47.0	53.8	14.9	18.0	26.8
	Head stock	50	-	-	85.1	-	-
	Support	-	-	7.7	-	-	1.7
	Total	100	100	100	100	100	100
Hydraulic equipment	Hydrostation	50	33.3	70	26.4	23.8	67
	Servocontrol unit	50	66.7	30	73.6	76.2	33
	Total	100	100	100	100	100	100

The values T_r, R and K_t depend not only on the lathes themselves, but to no less an extent on the possibilities of rapidly searching out the defects (particularly in the DPCD) and eliminating them quickly. In light of this, it is advisable to carry out the following measures:

1. To introduce a method for restarting the DPCD by replacing the faulty register for a good one (with subsequent repair of the former), for which it is necessary to improve the spare parts supply system, to deliver registers and other DPCD modules to the customer by special order and also to provide servicing equipment capable of searching out the malfunctions and repairing the registers.

2. To equip the DPCD with positioning indication and automatic diagnostic units.

3. To raise the qualifications of the personnel servicing lathes with digital program control at user plants, particularly by organizing personnel training in courses at the plants manufacturing DPCD.

An overall approach is necessary for substantially increasing the reliability of lathes with digital program control: it is necessary to work simultaneously on improving the lathes themselves on the basis of reliable information concerning their operation and to insure realization of the measures which were mentioned.

It was revealed when performing the operation at individual plants that the down time for lathes with digital program control due to organizational causes exceeds the down time due to technical causes by a factor of two and more. In light of the fact that the cause for down time is not established everywhere when calculating the down time, the customer may get a faulty impression of it. Therefore a systematic and reliable accounting of the work of the lathes should be organized at all user plants, with the causes for periods of down time being identified (as it is done, for example, at the Kaluzhskiy Machine-Building Plant).

Much attention was also devoted to the questions of achievable accuracy and roughness of surface machined on these lathes during the operational studies of lathes with digital program control. The data which were obtained made special theoretical and experimental research necessary [2, 3]. As a result of this research, it was revealed that the machining accuracy and the roughness of the surface depend substantially on the technical level of the DPCD and the feed drives as well as on the quality of the cutting tool. In lathes intended for machining parts with second class accuracy (diameter and length within a range 75-630 mm.), it is necessary to use a DPCD and feed drives which insure movement of the lathe's final control elements (the carriage and slide) with a discreteness of one micron along the X axis and two microns along the Z axis.

Conclusions

1. Studying lathes with digital program control under operating conditions is one of the main sources for obtaining reliable information about their quality.

2. The completing items (the DPCD and the hydraulic equipment) are the elements which determine the reliability of the lathes which were studied.

3. The work which was performed made it possible to improve the mechanical units on the lathe models which were studied.

4. The efficiency of using lathes with digital program control depends substantially not only on the lathes themselves but on how correctly they are used and maintained. In this light, it is necessary to improve the system for maintaining lathes with digital program control on the users premises.

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EQUIPMENT FOR MOUNTING AND CLAMPING MACHINED LATHE SHAFTS

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 79 pp 30-31

[Article by V. N. Syroyezhkin, A. L. Umanskiy]

[Text] Production of Model 1B732F3 semiautomatic centering lathes with digital program control and model 1B732 semiautomatic hydraulic copying lathes have been put into production at the Moscow Machine Tool Plant imeni Sergo Ordzhonikidze. They are designed for turning parts such as shafts with a diameter up to 400 mm. (above the support carrier) and up to 2,000 mm. long.

These lathes are equipped with a universal carrier attachment consisting of a carrier device, a floating, spring-loaded pointed journal and, where necessary a tightening device which is mounted on the rear of the lathe spindle.

Standardized, double-jawed chucks are used for clamping the parts on centering lathes operating under large-series and mass production conditions. Readjustment of this type of chuck to clamp a part with a different diameter requires replacement of the jaws, which is a laborious operation. Furthermore, the range of diameters for the blanks being mounted cannot be adequately large, and therefore, such chucks are not used on lathes operating under single and small series production conditions, particularly on lathes with digital program control.

A semiautomatic, easily readjustable self-wedging carrier device has been designed and introduced for these lathes (Figure 1). This device will provide for readjustment to different blank sizes without replacing the jaws and for a significantly expanded range of diameters for the blanks being clamped.

As distinct from ordinary carrier units with pegs and ring clamps, it has several eccentric jaws with serrations on the working surfaces. The part being machined is wedged between the jaws at the initial instant of cutting, when the cutting force creates a relative motion of the part and the jaws. With an increase in the tortional force from the cutting forces, the tortional force transmitted by the device also increases automatically and it, therefore, operates reliably anytime chips are cut off.

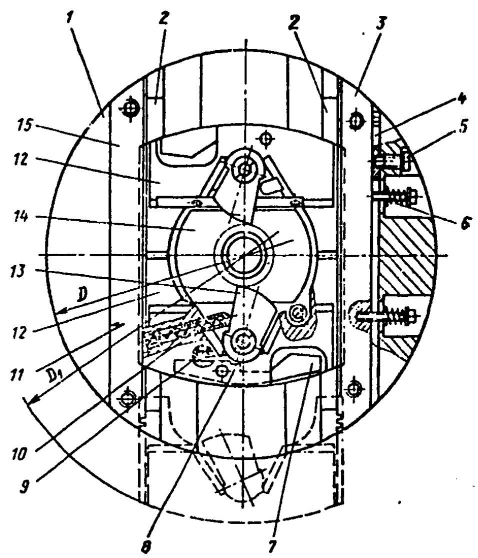

Figure 1. The Semiautomatic Wedging Device.

Similar devices are widely used on multiple-tool lathes at the Moscow Machine Tool Plant imeni Sergo Ordzhonikidze, where transfer of high torques is required.

A slot 11 is made in the housing 1 for the device. Toothed racks 3 and 15 are mounted in the slot using screws and rubber washers. Slide bars 12, the teeth of which mesh with the teeth of the racks, are mounted between them. Rack 3 is compressed to the groove wall by springs 6 mounted on screws by a wedge 4, which is set by screw 5.

The rotating eccentric jaws 13 which interact with the spring-loaded push rods 10 are mounted on the slide bars 12 on the axes. Also, on the axes of these slide bars centrifugal latches 7 are installed which interact the jaws 13 with recesses 8. The latches are tightened to the jaws by springs 9. Linear gages 2 are mounted on the frame 1 and a self-adjusting spherical stop 14 is situated in its conic opening.

The proposed carrier device prevents us to machine blanks with a broad range of diameters with the spindle rotation speed varying from the minimum specified for the given lathe the maximum, restricted by the strength of the device ($n \leqslant 1500$ rpm). It simplifies readjustment for various blank diameters and is relatively small in size and weight.

The engineering data for the device are as follows: diameter meter with slide bars retracted D = 400 mm. and with slide bars expanded D_1 = 530 mm., height = 90 mm. The limits of diameters which may be clamped are 65–350 mm.

(with a set of low jaws) and 25-32 mm. (with a set of high jaws). The weight is 26 kilograms.

The clamping eccentric jaw, the rapidly wearing element of the design, is manufactured from ShKh 15 steel and the working surface is tempered (HRC 58-62). The width of the jaws' working surface is selected within a range 15-25 mm., depending on the working conditions.

The profile of the working surface for the clamping eccentric jaw (Figure 2) is calculated according to the following formula:

$$l = \tan \alpha \ (\sqrt{L^2 - d^2 \sin^2 \alpha /4}) - d \cos \alpha/2);$$

$$R = (\sqrt{L^2 - d^2 \sin^2 \alpha/4} - d \cos \alpha/2)/\cos \alpha;$$

$$B = 2 \text{ arc sin } (0.75/R).$$

The tolerance for the dimension L is $\pm$ 0.2 mm. and for the dimension R, $\pm$ 0.5 mm.

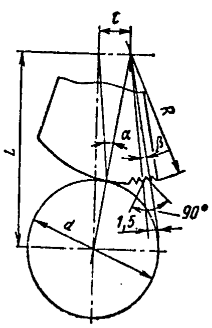

Figure 2. Profile of the working surface for the clamping jaw.

The floating pointed journal (Figure 3) has a beveled bushing 6 which mounts in the lathe spindle. The pointed journal 5, which has a bolt 4 screwed into it, is located in the center opening of bushing 6. The pointed journal interacts with push rod 3 supported by a pack of Belleville spring washers 2 by means of this bolt. The latter is installed in casing 7 screwed into bushing 6. The pack of spring washer is pretightened using screw 1.

The throat clearance of the pointed journal with regard to this spherical stop for the carrier device is regulated using bolt 4 (cf. position 14, Figure 1). This type of journal design permits its throat clearance to

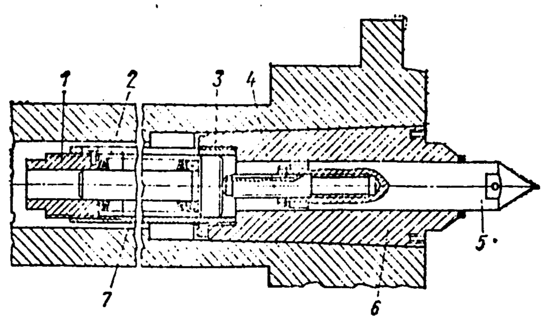

Figure 3. The Floating Pointed Journal.

be regulated for centering holes 1-16 mm. in diameter without additional machining. The journal throat clearance is regulated so as to create a 10 mm. deformation on the pack of spring washers when basing a part along the spherical stop. The preliminary compression force P of the spring washer pack is selected from a calculation of the maximum radial force which is capable of wrenching the part from the adapter, having displaced the journal in the direction of the axis. The values of force P as a function of the weight m of the shafts being machined are given below.

m_{max}, kg	600	800	1250
P, kgf*	750	1000	1500

Because of design considerations and in order to create the necessary force on the pointed journal, the pack consists of 50 NM 45 x 25 x 3 spring washers (State Standard 3057-54). The spring washers are stamped from 60S2A sheet steel. The beveled bushing is manufactured from 20Kh steel with base surfaces being cemented. The play on the beveled bushing surface relative to the central base opening is not more than 0.01 mm. and the roughness $R_a < 0.63$ microns. The central base opening is made according to the fifth quality specification; roughness $R_a < 0.63$ microns. The pointed journal is manufactured from 65G steel and is tempered (HRC 48-52). The base surface of the journal is formed following the fourth quality standard with a tolerance field g4; roughness $R_a < 0.63$ microns. The play of the cone relative to the base surface is no more than 0.01 mm.

All centering lathes produced by the Moscow Machine Tool Plant imeni Sergo Ordzhonikidze are equipped with the described pointed journal.

When machining parts with $m > 1250$ kg which are out of balance, significantly increasing the radial force P and auxiliary tightening of the center is used. The main part of the tightening device (Figure 4) is a rotating pneumatic cylinder 1 (Type TsV-150), attached by screws to an adapter

*Tr. note--To convert kgf to Newton (N), the conversion factor is 9.806.6508E+00.

flange 2 screwed onto the threaded end of the lathe spindle. The pneumatic cylinder rod constantly interacts with a push rod tightening the front journal.

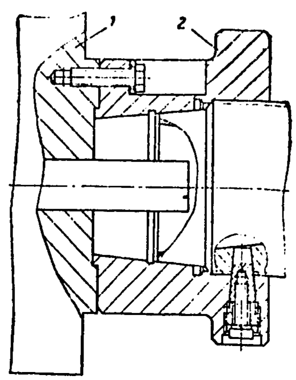

Figure 4. The Tightening Device.

The described universal adapter works in the following manner: in the initial position, the eccentric jaws are opened and held by the recesses of the centrifugal latches. The part is mounted on the lathe's journal axis and is shifted to the side of the spherical stop using the tail spindle of the tail stop.

Here, the front journal compresses the pack of spring washers. The throat clearance of the front journal is selected so that when the part is mounted on the spherical stop, the pack of spring washers creates a specific force insuring the constant positioning of the part on the journal axis. Then the spindle is set in rotation. The latches rotate on their axis under the effect of the centrifugal force, freeing the jaws which, under the effect of the springs, press themselves against the surface of the part. At the instant in which cutting begins, the part is wedged between the jaws.

The part is released when the spindle is stopped. Using a special wrench, the clamping jaws are manually removed from the part surface and the centrifugal latches secure them. Then the tail spindle of the tail stop is moved away and the part is removed.

The wedge is removed to readjust the unit to clamp a part with another typical size. Here, the springs release the rack, freeing the slide bars. The latter are moved along the racks and are set on the necessary size according to the linear scales. Then the wedge is put in place and set with a screw.
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